THE ROYAL ENGINEERS JOURNAL—DECEMBER 1960

VOL LXXIV. No 4

THE ROYAL ENGINEERS JOURNAL

Vol LXXIV DECEMBER 1960 No 4

CONTENTS

PUBL ... EERS

All co ... itution

AG ... M

INSTITUTION OF RE OFFICE COPY

DO NOT REMOVE

METROPOLITAN COLLEGE

Specialised Postal Coaching for the Army

PRACTICAL AND WRITTEN

Staff College and Promotion Examinations

Specially devised Postal Courses to provide adequate practice for written and oral examinations—All maps supplied—Complete Model Answers to all Tests—Expert guidance by experienced Army Tutors—Authoritative Study Notes—All Tuition conducted through the medium of the post—Air Mail to Officers overseas—Moderate fees payable by instalments.

* * *

ALSO INTENSIVE COMMERCIAL TRAINING FOR EMPLOYMENT ON RETIREMENT

Write today for particulars and/or advice, stating examination or civilian career in which interested, to the Secretary, (M12), Metropolitan College, St. Albans

ST. ALBANS

Telephones
ABERDEEN 33355 INVERNESS 1331

WILLIAM TAWSE
LIMITED

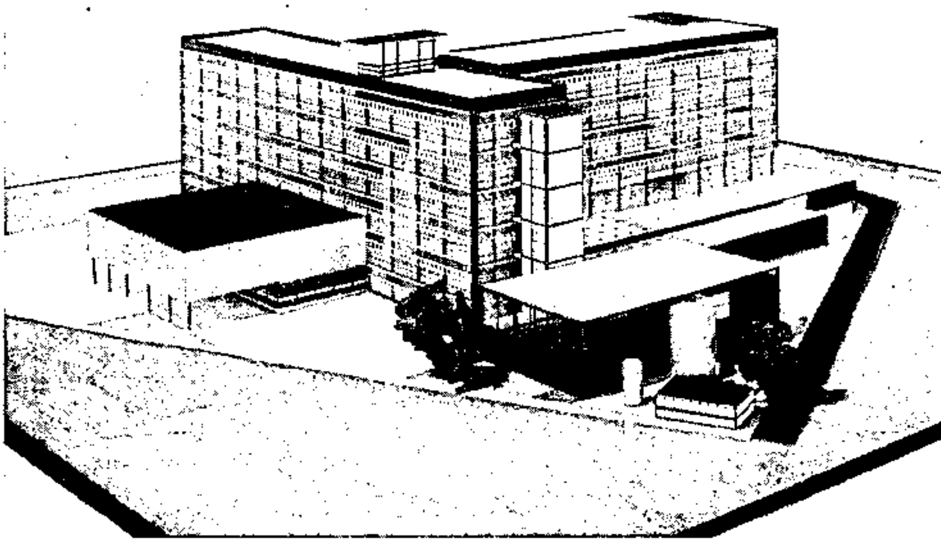
CIVIL ENGINEERING AND
PUBLIC WORKS CONTRACTORS

ANGUSFIELD · ABERDEEN
and
CARSE · INVERNESS

NEW OFFICES FOR

THE NORTH THAMES GAS BOARD

Carnwath Road, Fulham, S.W.6



Architects and Industrial Consulting Engineers
Messrs. E. R. Collister & Associates

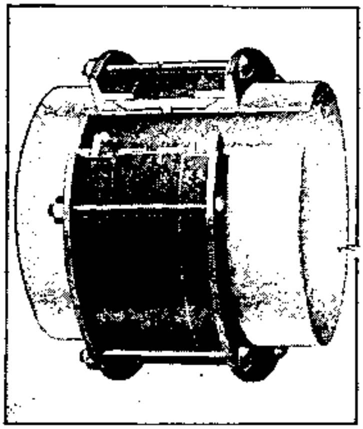
BUILDERS

TROLLOPE & COLLS

(Established 1778)

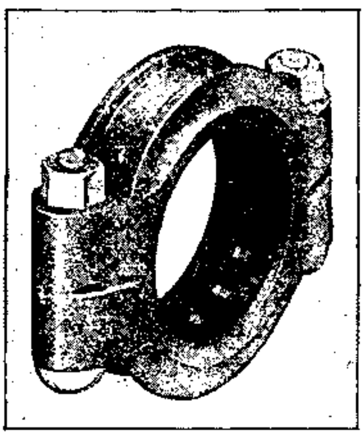
TROCOLL HOUSE, 1 NOBLE ST., GRESHAM ST., E.C.2

Telephone Number MONarch 3000 (40 lines)



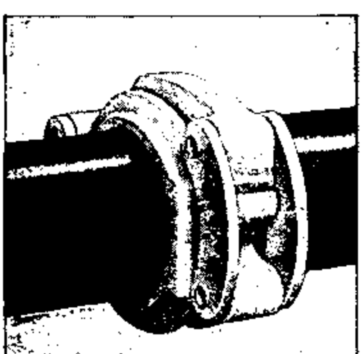
VIKING JOHNSON
FLEXIBLE COUPLINGS

for plain ended pipes, 6° of flexibility on sizes up to 24 in. diameter. Fitted by unskilled labour. When laid, competitive in price with lead and yarn joints.



VICTAULIC
FLEXIBLE JOINTS

for Service pipelines are ideal for emergency purposes. The standard bolted joint can be fitted by unskilled labour in under two minutes per joint.



THE VICTAULIC
TOGGLE JOINT

without nuts and bolts, is easily fastened mechanically, in a few seconds.

The War Office, India Stores Department and High Commissioner for Pakistan have standardized Victaulic Joints for mobilization work.

Copy of our Victaulic Catalogue will be sent on request.

VICTAULIC

THE VICTAULIC COMPANY LIMITED

Manufacturers of Victaulic Joints and Viking Johnson Couplings

8 GOUGH SQUARE, FLEET STREET, LONDON, E.C.4

Registered Trade Marks 'VICTAULIC' and 'VIKING'

Bob's father didn't buy his first car till he was 38: and even then it was a secondhand job, with a dickey at the back where young Bob had to sit, come rain, come shine. Yet here's Bob buying a brand-new saloon while he's still in his twenties—thanks to UDT, who help him to pay for his car over the months instead of all at once.

UDT credit facilities are available to Servicemen of all ranks, at home or abroad. Wherever you are stationed, you can buy any make of car you choose with UDT's help—quickly and easily: safely, too, because UDT is Britain's largest finance house, with long and wide experience of all aspects of credit finance.

If you are stationed abroad, write for our special free booklet—UDT Car Finance for H.M. Forces Overseas. If you are stationed in the U.K., get in touch with your nearest UDT office—the address is in the local directory—or tell your dealer you want to buy your car on credit through UDT.

UDT helps people to help themselves

UNITED DOMINIONS TRUST LIMITED · SERVICES DEPARTMENT · UNITED DOMINIONS HOUSE · EASTCHEAP · LONDON EC3

J. M. HILL

& SONS LTD.

BUILDERS & CONTRACTORS
TO
WAR OFFICE · AIR MINISTRY
MINISTRY OF WORKS · L.C.C.

WEMBLEY 7781

BY APPOINTMENT
TO HER MAJESTY THE QUEEN
HATTERS

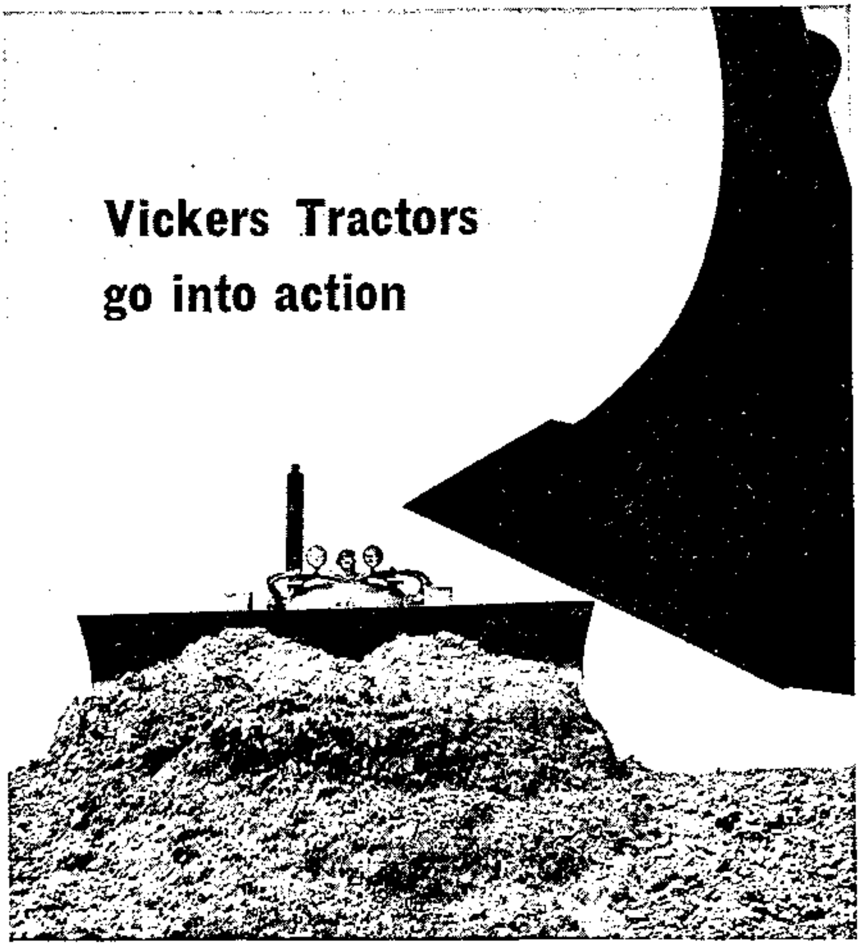
Herbert Johnson
(BOND STREET) LTD.

REGIMENTAL CAPMAKERS TO

ROYAL ENGINEERS

HERBERT JOHNSON *specialise in hats for every occasion — faultless hats made to suit you personally, with the same distinctive correctness that is observed in the making of all regimental headgear. Also available are impeccable accessories including regimental and club ties.*

38 New Bond St., London W.1.
Mayfair 0784
Weekdays 9 a.m. — 5 p.m.
(Thursdays 6.30 p.m.)
Saturdays 9 a.m. — 1 p.m.
40a London Rd., Camberley
(Wednesday afternoons only)



FIRST VICKERS VIGOR TRACTORS FOR BRITISH ARMY NOW IN SERVICE

Already some of these tractors ordered are on site on vital projects for the British Army. They are the first of the order for 60 Vickers Vigors, which was hotly followed by a repeat order for 49 more. The total of the two contracts including matched equipment is worth in the region of one and a quarter million pounds. Before placing the order the Army made the Vigor tractor undergo a long series of the most gruelling tests ever carried out on contracting equipment.

The Vickers Vigor tractor is the fastest, most efficient heavy crawler tractor ever built. Together with Vickers Onions earth-moving equipment it has been proved on big jobs all over the world.

VICKERS-ARMSTRONGS (TRACTORS) LIMITED

SCOTSWOOD WORKS NEWCASTLE UPON TYNE 5

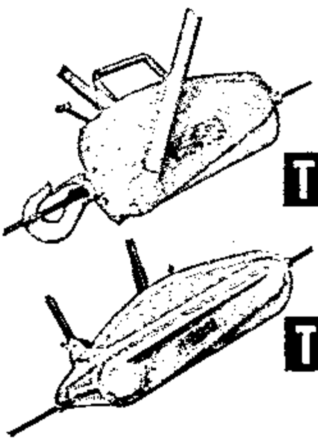
For the modern Army....

the **TIRFOR**

IN USE BY N.A.T.O. FORCES

For all Pulling & Lifting

whether it be ramp-loading, ground-cleaning, construction, or demolition, TIRFOR Machines can do the job.



T13 The TIRFOR T13 has a mechanical advantage of 43 and lifts a ton. The T35 has a mechanical advantage of 85 and lifts 3 tons.

T35 TIRFOR Machines give a controlled reversible pull over any distance. They can be carried and operated by one man.

TIRFOR LIMITED
ONE OF THE SIMM ENGINEERING GROUP
27 BROOMGROVE RD. SHEFFIELD 10

London: 'Phone. Terminus 6558 — Scotland: 'Phone. Kirkintilloch 2468 — S. Wales: 'Phone. Bridgend 4061

Full Banking Service

plus

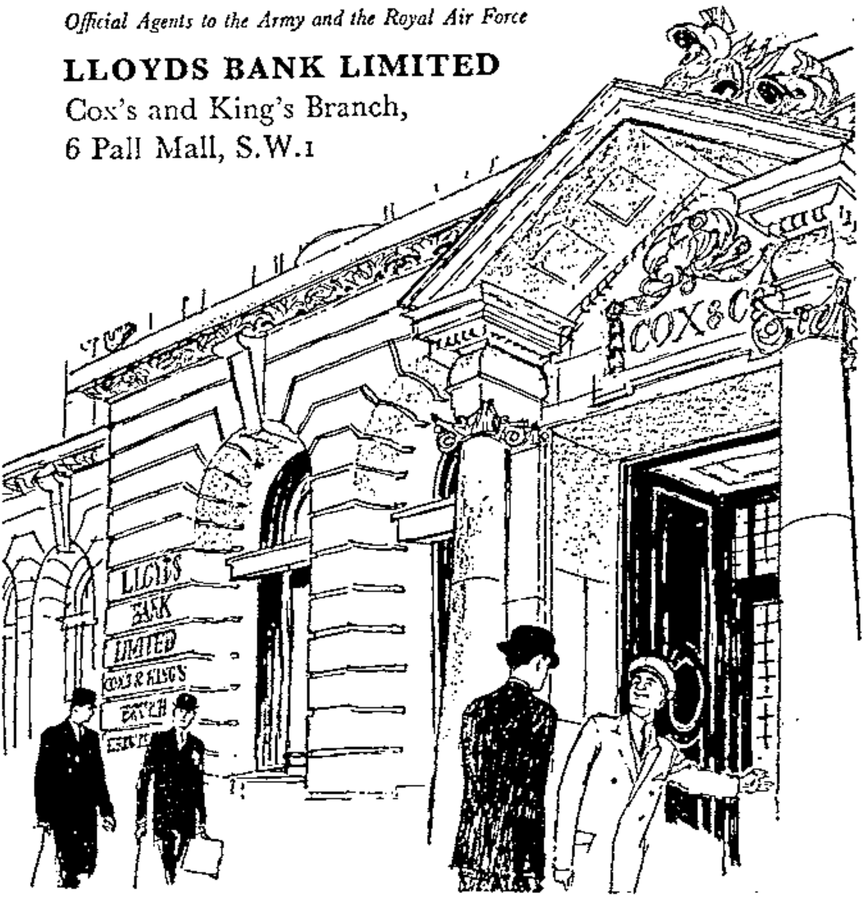
- The knowledge and reputation gained during more than 200 years puts us in a unique position to deal with the banking requirements of our Service customers.
- Equally we are very well equipped to deal with industrial and commercial business of which we have had wide experience.
- If you have any financial problem you wish to discuss, or if you require a loan for personal needs or finance for business purposes, please write or come to see us.

Official Agents to the Army and the Royal Air Force

LLOYDS BANK LIMITED

Cox's and King's Branch,

6 Pall Mall, S.W.1



THE COUNCIL OF THE INSTITUTION OF ROYAL ENGINEERS

(Incorporated by Royal Charter, 27 February, 1923)

Patron—HER MAJESTY THE QUEEN

President

Major-General Sir A. Douglas Campbell, KBE, CB, DSO, MC, MA 1957

Vice-Presidents

Brigadier A. G. Bonn, CBE, MC, MICE 1957
Major-General T. H. F. Foulkes, OBE, MA 1960

Elected

Lieut-Colonel E. L. L. Earp, OBE, ERD, TD, BSc, AMICE ... 1958
Captain K. V. Stewart, BSc 1958
Brigadier P. N. M. Moore, DSO**, MC, BA 1959
Colonel E. F. Kyte, OBE, BA 1959
Colonel I. H. Lyall Grant, MC, MA 1959
Colonel R. W. C. Smales, MA, AMICE 1959
Lieut-Colonel G. W. Kirkland, MBE, MICE, PIStruct.E, MInst.HE, FInst. Arb., MConsE 1959
Lieut-Colonel R. F. Parker, MBE 1959
Lieut-Colonel J. E. Weller, MC, MA 1959
Colonel H. C. G. Cartwright-Taylor, BA, AMICE 1960
Lieut-Colonel I. D. S. Brown, MC, BA 1960
Lieut-Colonel J. R. Cave-Brown, MC, BA 1960
Major-General D. C. T. Swan, CB, CBE 1960
Major G. B. Duffy, MC 1960
Lieut-Colonel R. H. Braybon, MBE, TD 1960

Ex-Officio

Brigadier A. P. Lavies, CBE, MA ... ... BGS, RE
Colonel A. G. Peart, OBE, BA ... ... AAG RE
Brigadier E. F. Parker, OBE, BA ... ... Comd SME
Brigadier A. H. Dowson, OBE, *ADC*, BA, FRICS ... ... D Survey
Colonel A. L. Hicks, OBE, BA, AMICE, AMIMechE, AMIEE ... D/Comd SME
Brigadier H. W. Kitson, CBE, MA ... ... Comd, Trg Bde, RE
Brigadier A. G. P. Leahy, OBE, BA. ... ... Comd, Tn Centre RE
Brigadier R. B. Muir, CBE, BSc, MICE, AMIMechE, AMIEE, AMIStruct.E ... ... Brig. "E" (Q Services)

Corresponding Members

Lieut-Colonel A. R. Currie, DSO, OBE, *New Zealand Military Forces* ... 1 January, 1949
Colonel C. Linsell, OBE, MC, *Union Defence Force, South Africa* ... 1 February, 1956
Brigadier A. T. J. Bell, OBE, *Australian Military Forces* ... ... 15 August, 1960
Colonel D. W. Cunnington, GM, CD, *Canadian Army* ... ... 2 September, 1958

Secretary and Editor R.E. Journal

Brigadier J. H. S. Lacey, CBE, BA ... ... 15 December, 1958

Bankers

Lloyds Bank, Ltd., Cox's and King's Branch, 6 Pall Mall, SW1

4,000 1.12.60

THE ROYAL ENGINEERS JOURNAL

Authors alone are responsible for the statements made and the opinions expressed in their papers

VOL. LXXIV

CONTENTS

DECEMBER, 1960

Corps Notes

On 26 October last the Chief Royal Engineer presented to the Queen's Private Secretary nine volumes of the History of the Corps of Royal Engineers which cover the period 1066 to 1946. Each volume, in accordance with Her Majesty's wishes, is bound in red leather and bears the Royal Monogram. Inside each volume there is a bookplate on which is printed an illuminated Corps Badge (the Royal Arms) and the words: "*Presented with our humble duty to Her Majesty the Queen, Our Patron, by the President and Members of the Institution of Royal Engineers, October 1960.*"

The following day the Chief Royal Engineer received a letter from the Queen's Private Secretary which read:—

Buckingham Palace

27 October 1960

Dear General,

The nine volumes of the History of the Corps of Royal Engineers which you brought here yesterday have now been laid before the Queen.

I am commanded by Her Majesty to convey her sincere thanks to you and to the Royal Engineers in giving her this history which, as Colonel-in-Chief of the Corps, she is proud to possess; she also greatly appreciates your kindness in having it so beautifully bound.

Yours sincerely,

Michael Adeane.

General Sir Kenneth Crawford, KCB, MC.

* * * * *

The Corps will wish to congratulate Lieut-General Sir William Stratton, KCB, CVO, CBE, DSO who has been appointed Colonel-Commandant, Royal Engineers in the place of General Sir Brian Robertson, GCB, CBE, KCMG, KCVO, DSO, MC whose tenure has expired.

* * * * *

Our congratulations are also extended to Captain P. C. Harvey, Royal Engineers on his appointment as the Army Equerry to Her Majesty the Queen.

* * * * *

A belated honour has recently been paid to the late Lieut-General Sir Ronald Charles, KCB, CMG, DSO, one time Chief Royal Engineer. On 31 July last the town of Landrecies inaugurated a memorial to him to mark the occasion of the liberation of the town from the Germans on 4 November 1918 by the British 25th Division at that time commanded by the then Major-General Charles. Although this inauguration took place over forty years after the event commemorated, the ceremony was an impressive one.

The Prefect du Nord, the Mayor of Landrecies and the British Consul from Lille attended, together with a detachment of the Roubaix Branch of the British Legion with their Standard and representatives of the Commonwealth War Graves Commission. After a procession through the town the memorial was unveiled by the Consul; the procession then moved to the town's Cross of Sacrifice where wreaths were laid in remembrance of the fallen in two World Wars and the President of the Roubaix Branch of the British Legion delivered the Legion Exhortation.

* * * * *

A singular honour was paid to a Royal Engineer Territorial Unit on 15 October last when 113 Army Engineer Regiment (TA) received the Freedom of the City of Birkenhead.

* * * * *

To commemorate the close association of the Corps with the Maralinga Range Support Unit an inscribed silver rose bowl has been presented to the Royal Australian Engineers.

* * * * *

The Engineer-in-Chief has recently visited Canada and the United States and, whilst in Washington, he presented a set of volumes of the History of the Corps of Royal Engineers to the United States Engineer Corps to be held in their Library at Fort Belvoir.

* * * * *

Mr A. C. Davidson Houston was recently commissioned by the Corps Committee to paint a portrait of Glubb Pasha—Lieut-General Sir John Glubb, KCB, CMG, DSO, OBE, MC. The portrait, which depicts General Glubb in Arab Legion uniform, now hangs in the Small Ante-Room of the Headquarter Mess at Chatham; it was displayed for the first time on the evening of the Corps Guest Night held at Chatham on 24 November last.

* * * * *

59 Field Squadron RE, less one troop, moved from Chatham to the South Cameroons last August to give engineer support to the King's Own Border Regiment. Together with 160 Works Section RE it has been engaged in assisting the WD Works Organization in the provision of hutting and basic services, and have also been engaged on road maintenance and bridge repair. The very heavy rains in the area at this time of year have made construction work at the speed required a formidable task, but the bulk of the work has now been successfully completed.

* * * * *

Several units have carried out successful and imaginative training during the summer, and from many interesting items two are particularly worth mentioning. 48 Field Squadron of 38 Corps Engineer Regiment built a 130-ft reinforced concrete bridge for the Forestry Commission at Plashetts in Northumberland, which was opened by the CIGS, Field Marshal Sir Francis Festing, on 18 September. Later in the same month a POL exercise, to study the new Stage II POL pipeline system, was held at Chatham. For this a complete shore installation was set out at Upnor, and petrol was pumped ashore into storage tanks from a tanker in the River Medway. The exercise was widely attended and valuable lessons were learnt.

* * * * *

A considerable reorganization of Engineer units has been taking place in Singapore and the new units, which have emerged phoenix-like from the ashes of the old, are the Engineer Base Installations Singapore, 84 Survey Squadron RE, and 75 Malay Field Squadron. The first and last of these are to be commanded, and all are to be administered, by a new unit, HQ Engineer Base Group, Singapore.

* * * * *

During the last few months there has also been a gradual reorganization of the Army Apprentices' Schools. Apprentices learning all RE trades are now taught at Chepstow, with the exception of those wishing to become vehicle mechanics who are trained at Carlisle.

* * * * *

The Training Brigade RE is to be congratulated on its outstanding successes at this year's Army Athletics Championships and in the Army Rifle Association Meeting at Bisley. In the Athletics Championships 3 Training Regiment broke three Army records and equalled another, won nine events and scored more points than any other unit has done before in these Championships. At the Bisley Meeting, 2nd Lieutenant R. Ellis of 1 Training Regiment RE came first in the Young Officers' Cup and Sergeant R. G. Merritt RE won the Regular and Territorial Armies' Cup. 1 Training Regiment RE won the Britannia Trophy. 3 Training Regiment A Team were second, and their B Team fourth, in the Royal Ulster Rifles Cup and Lance-Corporal B. Tainton RE, of 3 Training Regiment, shot splendidly to be placed fourth in the Roupell Cup, only two points behind the winner.

* * * * *

A Branch of the RE Museum has recently been opened at Aldershot. It is administered by 1 Training Regiment RE, the descendants of the Chatham based Training Battalion Royal Engineers. The items exhibited come from the RE Museum, Chatham and include those best suited to teach the Sapper recruit the history and traditions of the Corps.

* * * * *

A unique collection of medals has kindly been presented to the RE Museum by Mr C. A. Milner of Cyncoed, Cardiff. They are the medals of the late CSM Sydney Augustus Milner who had the distinction of having the regimental number 1 in the Territorial Army. He had previously served in the Submarine Miner Volunteers from 1885 and was given the regimental number 1 on re-attestation into the Territorial Army on 1 April 1908. He served with the Severn Divisional Engineers (TA) from 1908 until 1914, and from 1914 to 1919 in the Welsh Regiment. He died in 1948, aged 84 years.

* * * * *

On 15 October last, Frank Mayell celebrated his hundredth birthday. He enlisted in the Corps as a mason in 1878. He served in Gibraltar, Cyprus, Egypt, Suakin and the Sudan. On leaving the colours he became the landlord of the Rising Sun, Bradford on Avon where he remained for over fifty years and, at the age of 95, he was the oldest licensee in the country.

He is at present in the Wiltshire County Welfare Home. To mark his hundredth birthday the Queen, as our Colonel in Chief, graciously sent him a congratulatory telegram, Lieut-General Sir Francis Nosworthy presented him with Free Life Membership of the Royal Engineer Association and other Association insignia, and the Wiltshire County Council presented him with an illuminated address.

* * * * *

This issue of the *Journal* contains a paper by Brigadier R. B. Muir that will be read and subsequently discussed at a Joint Professional Meeting, to be held in the evening of 2 February 1961, at the Institution of Civil Engineers. It is hoped that as many members as possible of our Institution will attend the meeting and take part in the discussion. Full details of the arrangements for the meeting will be published in the January 1961 *Supplement to the RE Journal.*

* * * * *

These notes would be incomplete without a reference to last October's "RSMs' Convention"—possibly a unique occurrence in the history of the Corps, or indeed in the Army, in that fifty-five RE Regimental Sergeant Majors were gathered together simultaneously in one place. The aim of the convention was to bring the RSMs up to date in all Corps matters and to obtain their views on problems resulting from the reduction in the size of the Corps, the disappearance of National Service and the re-establishment of a long-service Regular Army. Problems connected with today's Reserve Army were also discussed. In general the talks centred around morale, discipline, drill, dress, training, recruiting, pay and other rank promotion prospects, Corps publications including *The Sapper*, the RE Museum and customs of the service. The Officer i/c RE Records spoke on Records matters in the Regular and Reserve Armies. The RSMs visited the Training Brigade RE at Aldershot, the SME at Chatham, the Transportation Centre at Longmoor and the Junior Leaders' Regiment at Dover.

The Chatham Branch of the Royal Engineers Association entertained them at a social evening that will live long in the memory of Branch members.

The gathering of so many Regimental Sergeant Majors did not go unobserved in the local or national press, and a few of the RSMs and the Engineer-in-Chief, who visited and spoke to the RSMs at Aldershot, were "interviewed" on the television.

Paper to be discussed at the first joint meeting of the Institution of Civil Engineers and the Institution of Royal Engineers which will be held at the Institution of Civil Engineers on 2nd February 1961.

Engineer Support to the Christmas Island Nuclear Tests of 1958

By Brigadier R. B. Muir, CBE, BSc, MICE, AMIMechE, AMIEE, AMIStructE, MBIM

Synopsis

The author of this paper, who was Chief Engineer for the series of nuclear tests carried out at Christmas Island in the mid Pacific Ocean in 1958, describes the multiplicity of civil engineering work required to stage these tests. The impact of the complete isolation of the site from a developed area as well as the exacting time factor which governed planning and execution are discussed. The paper covers roads, airfields, and building construction work, and also the provision of utilities. Local production and utilization of crushed coral aggregate and the laying of bituminous surfacing are described. Unlike the equivalent United States nuclear tests at Eniwetok where all of the engineer work required was undertaken by civilian contractors, this works programme at Christmas Island was carried out by Royal Engineer units assisted by appropriate Army support units, and the paper discusses the organization and methods of control which were adopted. Reference is also made to damage control and to the general question of training of the young civil engineer.

Introduction

Aim

The aim of this paper is to describe the engineer effort involved in the mounting and execution of the nuclear tests carried out in the Christmas Island area during 1958.

Content

From a purely civil engineering point of view there is little to record of an unusual technical nature. Interest perhaps lies more in the exacting time factor which governed planning and execution; in the wide range and complexity of the work involved; and in the complete isolation of the site from a developed area.

The paper is presented under the following main headings:

Background
The 1958 engineer requirement
Organization
Planning
Control and supervision
Key engineer activities
Damage control
Factors affecting execution
Conclusion

Photo 1. A typical high yield test result.

Engineer Support to the Christmas Island Nuclear Tests of 1958

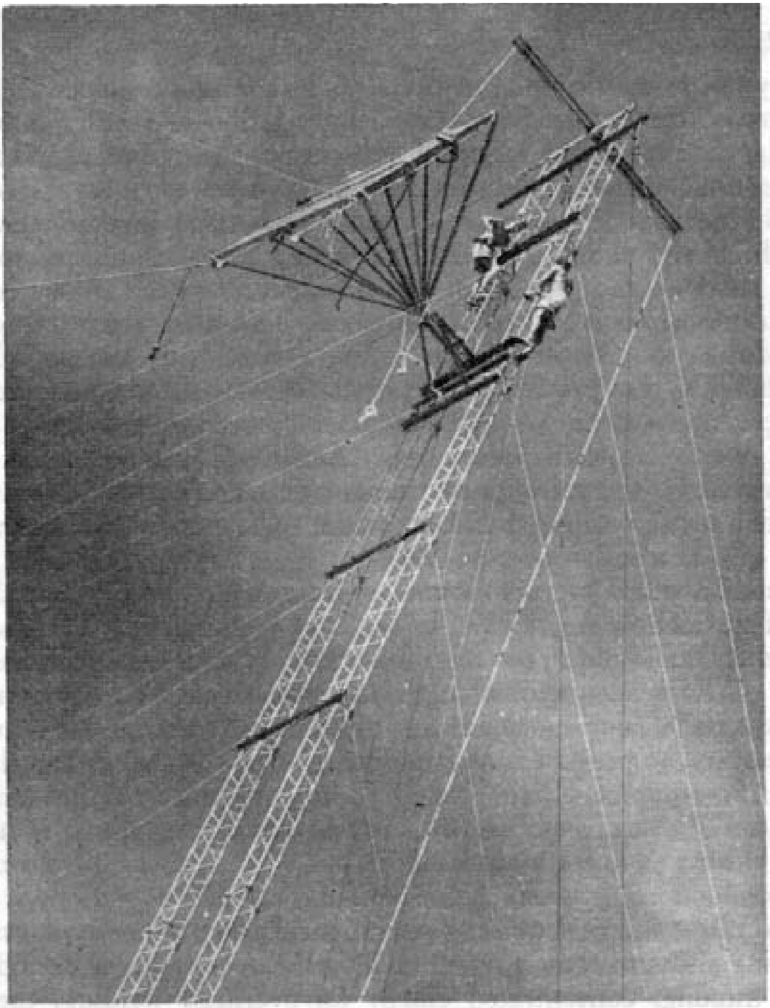


Photo 2. Sappers erecting a BICC twin mast, 130 feet high, with reflecting aerial.

Engineer Support to the Christmas Island Nuclear Tests of 1958 - 2

Background

Nuclear Tests Programme

It might be helpful as a background to summarize from press reports the programme of nuclear tests held in the Christmas Island area. "Grapple" is the name which was given to a Joint Task Force charged with responsibility for setting up and carrying out these nuclear trials. The tests, all of which were completed successfully, are enumerated below in chronological order.

May/June 1957	A first series of thermo-nuclear firings held in the vicinity of Malden Island (some 400 miles south-east of Christmas Island), using Christmas Island as a base for the operation.
November 1957	Operation Grapple Xray—this also was high yield and was staged at Christmas Island. Thereafter all of the subsequent nuclear tests were fired in the Christmas Island area.
April 1958	Operation Grapple Yankee—further high yield testing in the megaton range.
August/September 1958	Operation Grapple Zulu—weapons in both the megaton and kiloton range were fired during this test series.

This paper deals specifically with the engineer work required in support of Operations Grapple Yankee and Grapple Zulu in 1958 (Photo 1). These were the last nuclear trials to be completed before the Government of the United Kingdom suspended nuclear testing voluntarily for an indefinite period. It is not without interest that as early as July 1957 the United Kingdom Government took the initiative in this connexion, when the Foreign Secretary, on behalf of the United Kingdom, the United States, France and Canada, presented to the sub-committee of the United Nations Disarmament Commission a proposal that a group of experts should meet at an early date to proceed with the design of an inspection system to control a general suspension of nuclear tests. As is well known, this Conference of experts met at Geneva in July and August of 1958, and was attended by representatives from the United Kingdom, the United States, France, Canada, the Soviet Union, Poland, Czechoslovakia and Rumania. The delegates subsequently reported to their respective Governments.

Description of Christmas Island

(A) *Historical*

It was on Christmas Eve 1777 that Captain Cook, sailing in HMS *Resolution,* first landed on Christmas Island. He found it uninhabited, and during his stay planted the first coco-nut palms on the island. For the next fifty years after its discovery, Christmas Island remained unoccupied, except for the enforced and temporary presence of shipwrecked crews. Traces of wreckage of sailing ships can be seen to this day strewn along the eastern coast of the island which borders a deep bay, aptly called the Bay of Wrecks (Fig. i). Later British and American whalers began to call occasionally to rest their crews and to gather sea birds' eggs. In 1888 Captain Wiseman, in HMS *Caroline,* took possession of the island formally on behalf of Her Majesty Queen Victoria.

Then in 1902 the British Government granted a lease to Levers Pacific Plantations Limited for the purpose of developing a local copra industry. The results of this enterprise were disappointing but the company planted some 70,000 coco-nut trees before finally deciding to abandon the island. In 1913 the lease was taken over by a London firm, Central Coconut Plantations Limited. This company is reputed to have made the first real attempt to map the island in detail. A somewhat bizarre humour is evidenced in its choice of the names "London" for the small fishing harbour, and "Paris" for a minute peninsula of land distinguished only by its complete barrenness —names which persist to this day.

During World War II, an American Task Force occupied Christmas Island from November 1942 to March 1946. After the war, the Colonial Office took over the island and installed a District Officer. Christmas Island thus became a part of the Gilbert and Ellice Islands Colony, which can claim to be the biggest colony in the world. In size it aggregates about 2 million square miles, but most of the area is ocean. There is still no indigenous population, but about 150 Gilbertese with their families are imported from other islands in the colony. Living in London village, alongside the port, they work for a tour of about two years on the coco-nut plantations, before returning to their permanent homes. The District Officer, with his Headquarters about 2,000 miles away at Tarrawa, has the dual role of administering the island together with its transitory native population, and also managing the local copra industry on behalf of the Government.

(B) *Topographical*

Christmas Island is situated in the mid-Pacific, about 2° north of the Equator and 1,200 miles due south of Honolulu in the Hawaian Islands. The North American Continent and Australia are some 4,000 miles away. It is a classic coral island and is the largest atoll in the world. Its maximum length is just over 35 miles from north-west to south-east, and it varies in width from about 20 miles at its broadest point to under 3 miles at the south-east tongue (Fig. i). Of its total area of 350 square miles enclosed by its coast line, more than 250 square miles are water in the form of lagoons. The island is fringed by a reef at from 50 to 150 yards from the shore, and beyond the reef the sea bed drops steeply into extremely deep water. Sea transports have to anchor about 2 miles out in the lee of the island, and cargoes are transferred into small craft for carriage into the port of London through a gap in the reef. During the months of October to January, the swell is sometimes so severe that the channel into the port has to be closed for several days at a time.

The ground is flat and the maximum height above sea level does not exceed 30 feet. There is little top soil, and vegetation consists of sporadic coarse grass, prolific evergreen bushes, and a number of coco-nut plantations. The island abounds with a variety of sea birds; principally terns, frigate and booby birds many of which are migratory. The terns nest twice a year in colonies of several million birds, and these can constitute a hazard to low-flying aircraft. Wild life is completely harmless, and consists principally of gerboa rats and numerous land and hermit crabs. Mosquitoes are relatively few and are non-malarial. The lagoons and surrounding sea abound with a wide variety of fish, including sharks, porpoise, baracuda, tuna, kingfish and mantarays.

Temperature varies little throughout the year. Day temperature averages 88°F, with a drop of about 10° at night. Humidity is always very high, in the region of 98 per cent. Yet the climate is far from unpleasant mainly because of the trade winds which blow almost continuously from the north-east at speeds of from 8 to 25 knots. Rainfall is quite unpredictable, and can range from nil in one year to 6 inches in 8 hours, with a maximum recorded annual rainfall of 190 inches. The water-table is high and in most places is not more than 2 feet below ground level. The island is outside the hurricane belt.

Development of the island up to 1958

Before the arrival of the American Force in 1942, the only buildings on the island consisted of the native huts in London village, one or two wooden bungalows and a number of sheds clad in attap, which were used for working the copra industry. Port facilities were non-existent. The road network was primitive, being little more than rough tracks serving the various coco-nut plantations.

As might be expected, the United States occupational force, which had a maximum strength of 10,000 troops, had a considerable impact on the development of island facilities. Throughout its stay this force was accommodated in tents. The Americans built an airfield, with a main runway (6,000 feet long and 100 feet wide) laid with compacted coral mud, and also a similar but smaller strip near by for emergency landings. About 40 miles of coral mud roads were laid approximately 12 feet in width. A channel was dredged into the port where wharves were constructed. Several miles from the airfield a POL tank farm was built.

In June 1956 advance parties of the first Grapple Task Force arrived on the island. This force built up rapidly to undertake work for the first nuclear test series in May/June of the following year. The channel into the port was found to have silted up to such an extent that it would not have been feasible to dredge it within the resources and time available. Instead, facilities for open anchorage of ships off the port were provided in the deep water beyond the reef. Anchorages were moored in about 30 fathoms of water. Difficulties of this operations were not lessened by the steep inclination of the sea bed which descended to a depth of over 70 fathoms within a few lengths of a ship.

The airfield built by the Americans was still in a fairly reasonable condition and some of the wooden buildings in its vicinity were capable of being used. Within a few weeks the emergency strip was made operational to take Hastings aircraft. The main runway was scarified, re-levelled, and covered with a minimum of 2 inches of lagoon mud in preparation for surfacing with asphalt, using crushed coral aggregate. Concrete touch-down and turning pads (8 inches thick) were laid at each end of the runway. The asphalt surface (to a nominal depth of 1½ inches) was laid in about four weeks and was completed in October of that year. Under the conditions obtaining this was a highly commendable effort on the part of the CRE (Colonel J. C. Woollett, CBE, MC) and 28 Field Engineer Regiment, which was under his command. It is very much to the credit of these sappers that this main runway, with very little rehabilitation work indeed, stood up well to the exacting conditions of the subsequent Grapple Operations. In fact this runway was not re-levelled and re-surfaced until 1959.

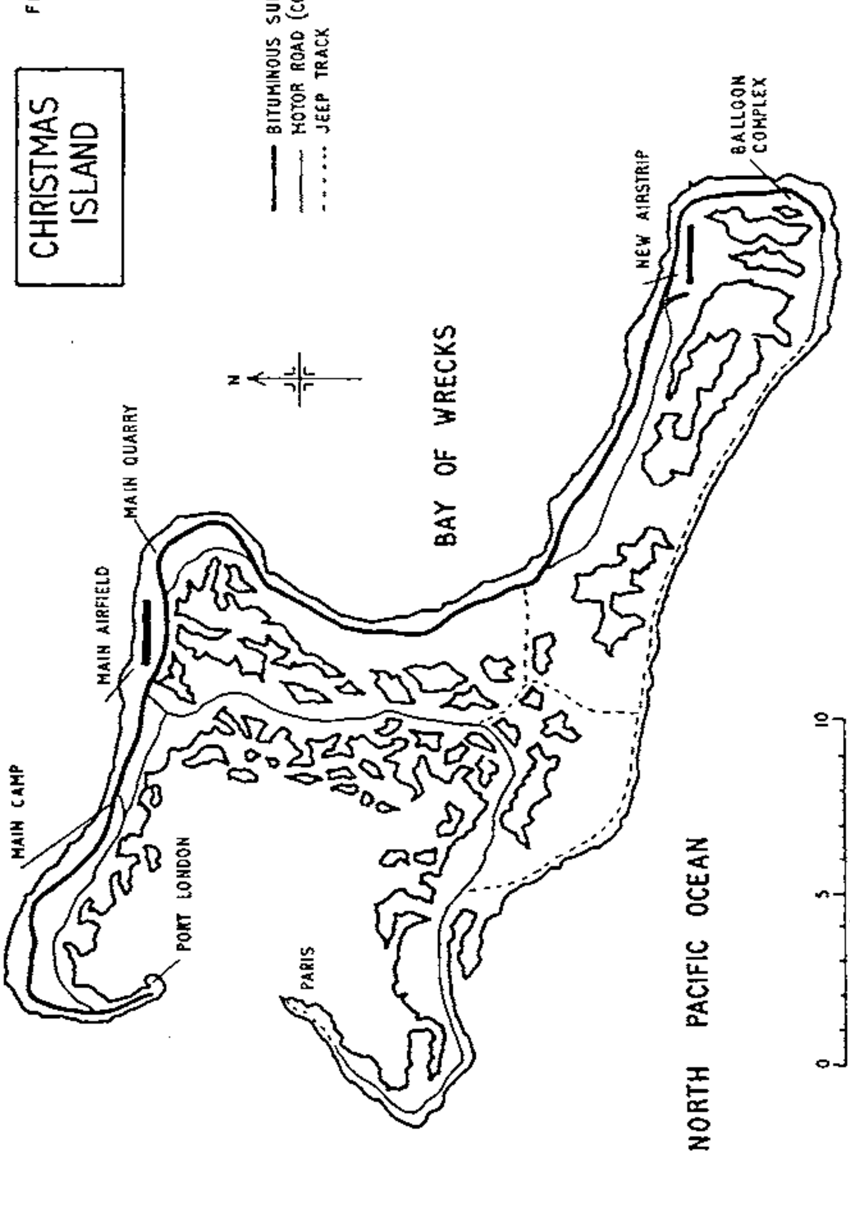

CHRISTMAS ISLAND
BITUMINOUS SURFACING
MOTOR ROAD (CORAL MUD)
JEEP TRACK
N
BAY OF WRECKS
MAIN QUARRY
MAIN AIRFIELD
MAIN CAMP
PORT LONDON
PARIS
NEW AIRSTRIP
BALLOON COMPLEX
NORTH PACIFIC OCEAN
0
5
10
SCALE ~ MILES

FIG. I.

Also during this period some 37 miles of the road network laid by the Americans were opened up again, and an additional 8 miles of new roads were built in coral mud. The steelwork in the American tank farm had so deteriorated due to the high rate of corrosion that rehabilitation was out of the question. Two new tank farms were built at more convenient locations. One (of ten 30,000 barrel tanks) was sited in the port area, and one (of seven 6,000 barrel tanks) was located alongside the main airfield.

Other engineer work on Christmas Island completed by March 1957 included a tented camp site (for over 2,000 all ranks) with just under forty wooden buildings for communal facilities, and over twenty buildings for operational requirements. Storage for 100,000 gallons of water was provided and also temporary power stations with a total installed capacity of 2,000 KVA. (An excellent description of these activities is contained in an article "The Christmas Island Base" by Colonel Woollett published in *The Royal Engineers Journal* of December 1957.)

Finally, in preparation for Grapple Operation Xray, another sapper force (25 Field Regiment) moved to Christmas Island in August 1957. These troops completed various instrumentation facilities on Christmas Island which enabled a successful nuclear test to be fired in this area for the first time in November of the same year. Before this regiment left the island in January 1958, about 1,000 feet super of asphalt surfaced hard standings had been laid at the main airfield. Additional hutted accommodation for messes had also been erected at the main camp and at the port.

The 1958 Engineer Requirement

Engineer work which had to be carried out during 1958 in support of Grapple Operations Yankee and Zulu are summarized under the following headings. This description of tasks is not comprehensive, but it should be sufficient to give an indication of the scope and the scale of the engineer effort required.

Test Mounting

(A) *New Building Construction*

This included a variety of laboratories; weapon assembly and test sheds; and buildings to house decontamination, photographic processing, and workshop facilities in support of the scientific effort. Many of these buildings had to be air-conditioned to strict tolerance limits. Purpose designed air-conditioning plant was provided in a few cases, but more generally Tenkon units (1 ton window type) were installed. Numerous power socket outlets were also an obvious requirement. An elaborate piped water system had often to be incorporated in a building, providing both fresh and distilled water at a variety of controlled temperatures. The use of flexible plastic piping reduced considerably the plumbing effort involved. Most of these new buildings were either steel or wooden framed with corrugated aluminium sheet cladding. They were lined with insulating fibre board, hardboard or aluminium sheeting, according to the use to which the particular building was put. Floors were of coral concrete and usually were covered with linoleum laid on bitumen, because of the obvious scientific necessity to keep dust to a minimum. Considerable internal ducting connected to extractor fans was often required to meet rigid health physics requirements.

Two laboratories were built in pre-cast concrete block construction. The blocks were made locally in block-making machines from coral concrete (maximum size of aggregate ½ inch). To allow adequate time for curing and drying out at least two weeks elapsed before use. These concrete laboratories were fitted with steel plate doors to resist blast effects.

As an example of the rate of construction, one laboratory of approximately 2,000 feet super was completed by twenty men in seven weeks. In all about 50,000 feet super of this type of new building construction were provided within nine months.

(B) *Effects Measurement Facilities*

Clearly the scientific value of these nuclear tests was dependent on the acquisition of comprehensive data (including film and still photographs) covering a wide variety of heat and flash, blast, and radiation effects, with recordings timed at micro-second standards. It was an engineer responsibility to provide facilities on the ground to enable scientific measurement equipment to be mounted and to operate in such a way that the information it recorded survived the test firing. These facilities varied from heavy steel shelters to numerous instrumentation lanes. The latter consisted mainly of a series of steel poles set in concrete together with totally enclosed chambers below ground level to provide protection for the associated electronic recording equipment. An obvious feature of every recording location was the necessity to site its position accurately. Additional trigonometrical stations were surveyed for this purpose by triangulation, and opportunity was taken to produce a revised map of the island on the 1,000 metre universal transverse mercator grid at a scale of 1 : 50,000.

The steel shelters were constructed from 8-feet cube units, the components for which were prepared in England or Australia. They were first assembled on the island to the required size by bolting using pneumatic bolt runners. Whilst adequate strength to these structures was transmitted through the bolts, continuous welding of joints internally and externally was often necessary, to prevent flash from penetrating the shelter and damaging the scientific equipment and records inside. Because of the number of welded steel shelters required the most economic procedure in terms of time and effort was to carry out much of this welding in a central workshops on line production methods. In view of the climatic conditions it was important to phase internal welding operations during the early morning and late evening shifts to reduce operator fatigue. After a short period of preliminary training, concentrated chiefly on overhead welding, the sapper welders achieved the necessary standard of workmanship, combined with speed of execution. As was the case with all operations of such a highly repetitive nature, attention was paid to devising the most effective timing for the frequency and duration of rest breaks. The assembled cube units were conveyed to sites by low loader and positioned using mobile cranes (10 and 25 tons). Steel shelters in the forward area were sunk into the ground for protection against blast, and were covered with 6 feet of soil retained by steel plates and sandbag walling to give the necessary protection from radiation. In rear areas, shelters were keyed into the ground to a depth of about 1 foot, and were made resistant to blast by the attachment of steel guys to reinforced concrete anchorages. False roofs in aluminium sheeting with generous over-hang provided shading from the strong tropical sun. Shelters were painted externally with aluminium paint both for weather protection and to reflect the sun's rays. Internally, wooden floors were covered with lino and walls and ceilings were painted with aluminium primer and white top coat to allow the necessary high standard of cleanliness to be maintained. Electric power to operate the installed scientific equipment was required at each site. Much of this equipment was electronic, and called for the installation of forced ventilation and air cooling plant to prevent its deterioration.

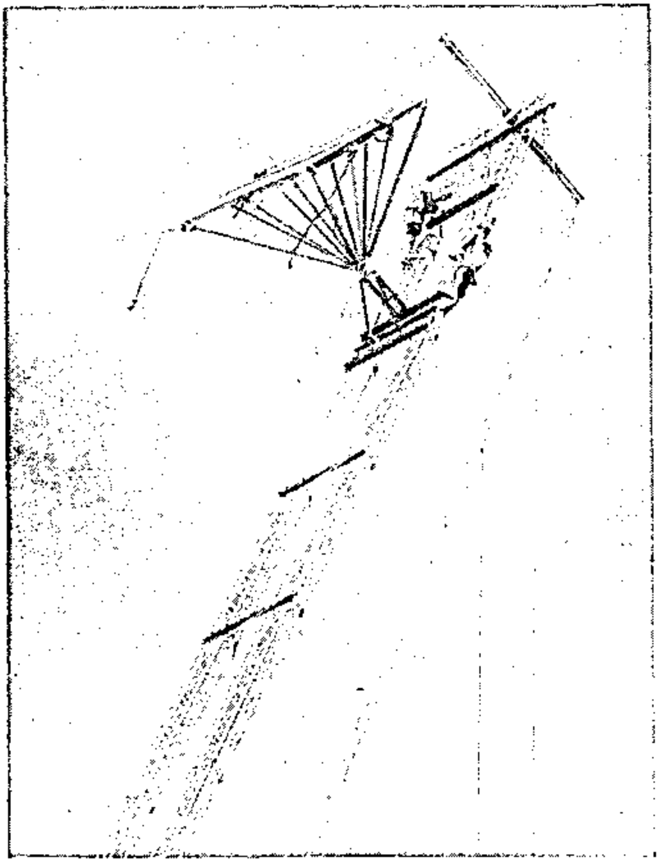


Photo 2. Sappers erecting a BICC twin mast, 130 feet high, with reflecting aerial.

For the elaborate ground telemetry system, numerous steel masts up to 150 feet in height had to be built. These were suitably guyed to concrete anchorage blocks. A closed television circuit was needed to operate between the forward target area and central control. Aerials were carried on BICC masts (triangular section) of light alloy lattice construction. A twin mast 130 feet high carrying a reflecting aerial weighing over 300 pounds could be erected complete within 36 hours (Photo 2). In common with a number of other special tasks sappers had to be trained *ab initio* in this type of work. There was never any shortage of volunteers for unusual jobs. One sapper who had developed into a highly skilled mast erector was asked once why he had volunteered. He replied "well I always did have a fear of heights and I decided now is my chance."

(C) *Royal Air Force Operational Requirements*

During Grapple Operation Zulu, moored balloons were used for the first time from which weapons in the kiloton range were suspended and fired. This called for the construction of anchorage blocks on virgin ground from which the balloons could be flown. In view of the close association between the Sappers and the Royal Air Force on these joint operations, it is perhaps not without interest that the Royal Engineers were the pioneers of military aviation. The first military aircraft were flown by members of the Air Battalion Royal Engineers formed in 1911. The Royal Air Force Balloon Unit, which operated the balloons during Grapple Zulu, had its beginnings in the Royal Engineer Balloon Depot which was introduced into the Sappers in 1850. The anchorage complex required for this operation covered an area of approximately 900 yards radius, with asphalt roads and hard standings equivalent to about 11 miles of roadway (12 feet in width). The main anchorage area consisted of a central anchor block (strength 42 tons) with over twenty other anchorages (varying in strength from 20 to 25 tons) located in a circular area of over 200 yards diameter. The complex included numerous other anchorages which provided a variety of alternative mooring and filling positions. Each anchorage was of high quality coral concrete enclosing heavy steel reinforcement, and was cast in the ground so that the top surface was flush with the asphalt surfacing so as not to impede the movement of the balloon winch lorries. The anchor block was designed to provide the desired anchorage loading by dead weight, and hence the action of ground friction added to the factor of safety. Excavations were required to a maximum of 5 feet below ground level. Although the water-table in this area was at an average depth of 2 feet below the surface, little difficulty was experienced in de-watering excavations using Johnson pumps (No 5 type). Aproximately 100 tons of prefabricated steelwork and 300 cubic yards of reinforced concrete were used on these anchorages. Elaborate earthing was an obvious requirement. The final megger tests on the copper strip earthing gave an average reading of 0.73 ohms, which was well within the permissible maximum of 7 ohms. The complex had also to be provided with area flood-lighting to enable balloon flying operations to be carried out during the hours of darkness.

Another operational R.A.F. task was the construction of target and bomb-line indicators. These conventional markings were produced on the ground by laying mix-in-place cement stabilized areas, the surfaces of which were painted with a sealing coat, a priming coat and a main coat of fluorescent paint. Observation towers of tubular steelwork to carry personnel and instruments had to be built for observation during bombing practice when conventional explosives were dropped.

Engineer work was required also to maintain detachments of the Task Force which were engaged in meteorological and test recording duties on the islands of Fanning (150 miles north-west of Christmas Island) and Malden (400 miles to the south-east). This covered such diverse tasks as the laying of beach roadways, the erection of telemetry facilities, the provision of electric power and water supply, and also road making, which included a modicum of bridge building in timber construction. In the main these were normal sapper tasks. Engineer plant (bulldozers, graders, concrete mixers, etc) had to be transported by sea from Christmas Island where it was always in much demand. The problem was to phase this work in such a way that the operational timing was met, with the least interference to progress on other work on Christmas Island.

Test Firings

Close support to the Royal Air Force and to scientific groups throughout the actual tests was another important engineer commitment. The provision of reliable electric power supplies during the firing stage was clearly essential to operate telecommunications, electronic recording equipment and vital air-conditioning plant. In rear areas this requirement was a continuous one, since the associated equipment had to function throughout the firing stage and thereafter. In forward areas generating sets and cooling plant had to operate up to the moment of the recording of a particular effect, after which they were put out of action by the test explosion.

There were about 100 generating sets at different locations in the forward area which had to be put into operation shortly before a firing by their sapper attendants, who were then withdrawn to a place of safety leaving these sets running. The development of a fault in a power unit after its attendant had been withdrawn would have immobilized the associated recording equipment, and this might have resulted in a serious gap in the information on test effects subsequently available. It is very much to the credit of these sapper attendants that no failure during a test ever occurred. This is all the more praiseworthy as so many of them were not fitters or engine hands by trade, but were field engineers trained locally to do the job. At shelter sites after scientific teams had made final adjustments to the recording equipment the shelter doors had to be bolted, and additional protective sandbag walling built quickly into position before evacuation of the sapper party. The personnel withdrawal operation which had to be planned and rehearsed to the last detail, incorporated meticulous safety precautions. For a balloon firing the withdrawal plan was a particularly interesting and exacting exercise. A considerable amount of heavy equipment had to be removed to a place of safety within an hour of the firing. This included cranes, gantries, handing platforms, earthing mats and area flood-lighting equipment.

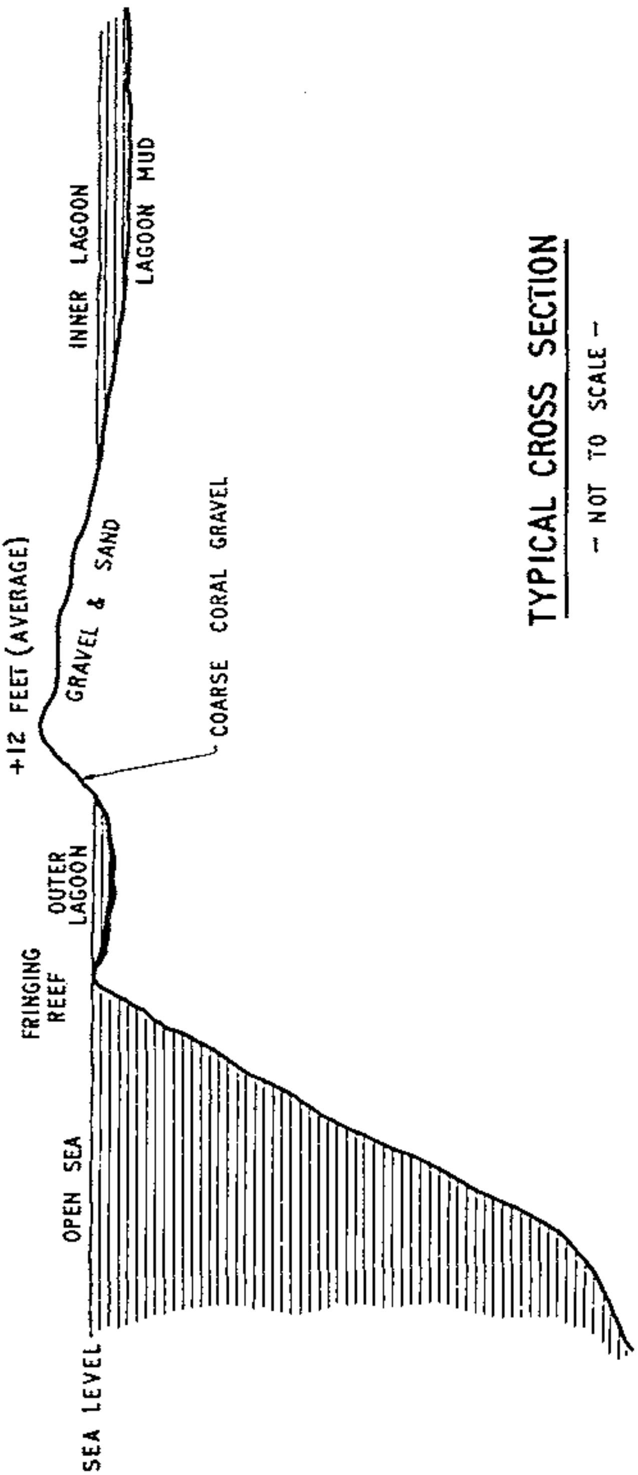
During re-entry into target areas after a burst, engineer reconnaissance and working parties followed close behind the scientific monitoring teams. Their first task was to erect road blocks and demarkation barriers so as to isolate physically any radiologically contaminated areas. Decontamination facilities had also to be set up speedily in support of activities of the health physics group.

Rehabilitation of the target area in preparation for the next firing was always a race against time. Often only a few days were available and hence this operation had to be pre-planned in very considerable detail. In spite of much of the explosive effect being calculable beforehand, there were obviously some imponderables. Thus alternative plans of action were required to cope with any eventuality. The work included the reopening of roads; rebuilding of shelter revetment; the erection of BICC masts, instrument lanes and telemetry facilities to replace those destroyed during firing; repair of control cables; and general rehabilitation of the target area.

Roads

Up to 1958 the roads on Christmas Island consisted of a consolidated coral mud carpet laid over a natural formation of coarse coral gravel. Coral mud when laid and compacted at optimum moisture content sets into a very

FIG. II.



TYPICAL CROSS SECTION

– NOT TO SCALE –

hard surface. Suitable deposits of this mud are fairly widespread in the inner lagoons of the island (Fig. ii). In winning it care has to be taken to avoid plant becoming bogged. The method frequently employed was dragline excavation, as the bearing capacity was rarely adequate for the use of Euclid scrapers.

Owing to the heavy traffic conditions imposed by test operations, and in spite of considerable effort being devoted to road maintenance, road surfaces became pot-holed or corrugated with alarming rapidity. This deterioration was accelerated by the periods of intense tropical rainfall which alternated with periods of prolonged drought. In the result:—

(*a*) Wear and tear on vehicles and plant was excessive.

(*b*) Valuable time was lost in transporting personnel and materials.

(*c*) Elaborate precautions had to be taken to avoid damage in transit to delicate equipment.

(*d*) Fatigue induced in passengers as well as drivers lowered efficiency.

(*e*) During dry spells dust became a major hazard in driving. Its settlement interfered with the operation of scientific equipment, and it created a nuisance in occupied areas.

(*f*) The maintenance effort to keep roads at acceptable standards became prohibitive.

For these reasons and also to enable substantial reductions to be made in the number of helicopters required for inter-communication, it was decided early in 1958 to embark on a bituminous surfacing programme of the main road network.

The bituminous mix was produced at a starmix 40 plant located about 3 miles from the main quarry. The surface was laid to an average depth of $2\frac{1}{2}$ inches and the mix selected was:—

	%
Coarse aggregate ($1\frac{1}{2}$–$\frac{3}{4}$ inch)	28.2
Medium grade ($\frac{3}{4}$–$\frac{3}{16}$ inch)	28.2
Quarry rejects	11.7
Fines	23.4
Cement	2.5
Bitumen (60/70)	6

The resultant surface wore extremely well. The edges of the carpet set hard and stood up well to the occasional vehicle which had to pull off the roadway. This was important as there were no curbs or containing shoulders. Marshall test results on the mix were satisfactory, as will be seen from the following table:—

	Specified	Average test results
Stability	$\nless$ 1,800 pound (Marshall)	2,600 pound
Flow	$\ngtr$ 0.16 inch (Marshall)	0.11 inch
Density	125 pound per cubic foot	130 pound per cubic foot

The mix was conveyed to Barber-Greene layers by tipper trucks, and no difficulty was experienced in transporting it for distances of up to 30 miles. The numbers required to operate a Barber-Greene were sixteen men per shift including two surveyors. Subsidiary laying plant comprised one stand-by Barber-Greene, two tandem road rollers, one Fordson tractor, one Bowser (1,000 gallon for pre-spraying) and one water truck. In order to avoid an extravagant use of asphalt accurate grading of the formation was essential. After the formation was graded and consolidated, the base was spread with MC 1 at a temperature of 170–190°F before laying began. The asphalt mix had a tendency to drag and extra shovel men were required to scatter asphalt behind the Barber-Greene to fill voids.

Before the surfacing operation, the formation was extended to an average width of 36 feet. On a double width roadway the bituminous surface was laid in two strips each of 12 feet thus giving a 6-foot wide berm on either side. The rate of laying per machine averaged $\frac{3}{4}$–1 mile of single strip per day. This work started in April, and by October it was possible to drive from the port to the south-east corner over a continuous asphalt surface. In all 55 miles of asphalt surface roadway were built of which just over 20 miles were double width (Fig i). On the remainder a single width strip (12 feet wide) was laid, and this extended from east of the main airfield to the balloon anchorage at the south-east point. This single strip surface was laid on the left-hand side of the 36-feet wide coral mud carriageway proceeding away from the airfield. Traffic going in this direction (ie towards the south-east point) was given right of way. Thus traffic proceeding from the other direction (towards the airfield) gave way to oncoming vehicles by temporarily pulling off the asphalt surface on to the amply wide coral mud carriageway on its left. This arrangement worked extremely well. It resulted naturally in very considerable reduction in road building effort and cost which was also justified by the relatively lower traffic density on this particular route.

These asphalt surfaced roads were routed through flood-free country which in many cases meant following close along the coast line. Considerable realignment of the existing roads was undertaken particularly along the route skirting the Bay of Wrecks, both to eliminate bends and to avoid areas liable to local flooding. Some 6 miles of new roadway across virgin country round the north-east point were built and surfaced with asphalt. Ample visibility throughout the road network was ensured by grading and by removing trees and scrub in the vicinity of the few corners which remained.

An entirely new coral mud road of about 12 miles in length was also built down the centre of the island to facilitate initial access to the balloon anchorage complex. The carriageway of this road was not less than 30 feet wide. This width tended to distribute consequent wear due to traffic. Its maintenance to reasonable standards was well within the capacity of two motor graders working part time. With an unsurfaced coral mud roadway the wider its formation the better, but clearly there comes a time when maintenance grading so reduces its level that either the wearing surface has disappeared entirely or it is below flood level. At this point its continuing use demands a major operation of laying and consolidating additional coral mud.

Airfields

A major airfield task was to increase the asphalt surfaced hard standings at the main airfield from about 100,000 feet super to about 1 million feet super. Clearly the laying of these hard standings called for a higher degree of accuracy than for laying roads, but little difficulty was experienced in bringing the operators up to the required standard. The most satisfactory sequence of rolling and the only way of avoiding camber was to roll from the inside outwards. Wooden blocks were surveyed at approximately 30-foot intervals to guide levels. In rolling the outside edge, it was important to ensure that the temperature of the mix did not drop to below 170°F before final rolling, otherwise there was a tendency for the edge to break.

An entirely new airstrip had to be built on virgin ground in the south-east area of the island capable of operating V bombers, to provide a diversionary landing ground to meet air flying safety requirements. This project was first mooted in July 1958. Preliminary survey, planning, final site selection and detailed ground survey were completed in time to allow the earthwork to be started within two months later. Good natural drainage was achieved by siting the strip along a low ridge giving a cross-fall of 1 : 100. The specification decided on was a minimum of 6 inches of compacted lagoon mud, surfaced with 3 inches of asphalt (2-inch binder course and 1 inch surface) (Photo 3). The shallow vegetable layer was first removed and the exposed surface levelled roughly using 14-yard Euclid motorized scrapers. Lagoon mud was then laid, levelled and compacted in layers of final depth of 3 inches, using graders and rollers. The mud was won entirely from below the water-table from near-by borrow-pits using dragline excavators (one 38 RB and two 19 RB). Material from below the water-table contains a lower proportion of sand and its natural lime content results in a chemical cementing action when compacted. This wet mud was transported from the borrow-pits to the laying site in 10-ton tipper lorries and in Euclid scrapers. After tipping, the mud was roughly graded into place and compacted with wobbly wheel rollers towed by size 4 tractors. These rollers were unballasted initially, then loaded to half ballast as the moisture content reduced, and finally full ballasted. Final grading followed by surface rolling using smooth-wheeled 8-ton rollers was carried out about twenty-four hours later when the moisture content had reduced to about 15 per cent. Tests of the completed base produced average CBR values of 70, and at times readings as high as 140 were recorded. Accurate control of levels was imposed by detailed survey, which placed a considerable strain on the five surveying teams (each of a surveyor, chainman and peg driver). Once the final set had taken place (at a moisture content of a little below 15 per cent), the surface was so hard that grading was practically impossible. This, combined with the difficulty of obtaining a satisfactory key between layers at anything less than 3 inches in depth, placed a high premium on working accurately to level throughout the mudding. In spite of inevitable interruptions to this work through test firings, the coral mud foundation for this air-strip was completed by one plant troop within three months. Asphalt surfacing began in December, and was completed early in 1959.

A final airfield task worth mentioning was maintenance of existing runways. In view of its age, specification, and its heavy and vital use, the bituminous surfaced runway at the main airfield had to be inspected regularly. Remedial action was taken at the first indication of deterioration either to the bituminous surface or to the concrete end pads. Two coral mud air-strips on Christmas Island situated about 20 miles apart, and a similar strip on Malden Island (400 miles away) had to be maintained for the operation of Hastings and Dakota intercommunication aircraft. During the year one of these strips on Christmas Island was extended by about 600 yards to meet Air Ministry requirements.

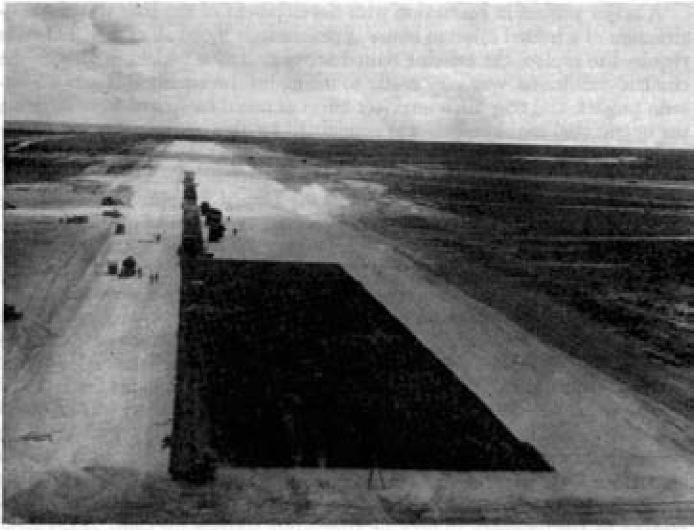


Photo 3. Sealing coat and levelling course being laid on the new V bomber airstrip.

Photo 4. An aerial view of initial development of the hutted camp showing the officers' and sergeants' messes sited overlooking the beach which is in the foreground.

Engineer Support to the Christmas Island Nuclear Tests of 1958 - 3 & 4

Base Development

A major project in connexion with development of the base was the construction of a hutted camp to house approximately 3,000 all ranks. This was required to replace the existing tented accommodation which, in view of the climatic conditions, was very costly to maintain. Inevitably this was a long-term project, and only such engineer effort as could be spared from securing the operational requirements was committed on this project. Owing to the scale of the operational tasks, residual engineer effort available was, at times, very little. Construction was principally in prefabricated timber hutting, the most of which was manufactured in the United Kingdom. Priority was given to providing communal facilities in messes. At the hospital an air-conditioned operating theatre and X-ray department were built together with about 8,000 feet super of hutted ward accommodation. New facilities were also provided for the island laundry, bakery and for Service workshops.

Communal mess buildings were sited in open squares overlooking the beach, and hutted accommodation was located to take full advantage of the prevailing wind (Photo 4). Installed kitchen equipment included oil fired ranges (72-inch) with fully automatic control equipment. Steam for jacketed boiling pans, wet steam ovens, serving counters and calorifiers was provided by a district low pressure system. Electric cooking equipment such as pastry ovens, grills and fish friers was also required. The project included the installation of a water-borne sewage system. Ablution blocks to serve the occupants of each group of ten huts were built. The plumbing load was increased by the necessity to provide alternative systems for using either fresh or raw water. This flexibility was essential because of the widely varying yield from time to time in the available sources of both types of water. The building of one ablution block took about six troop weeks to complete. By December about 80,000 feet super of communal mess buildings had been built in addition to sleeping huts for 1,000 all ranks, together with associated ablution blocks.

Emphasis was given to the provision of recreational facilities. Asphalt surfaced hockey pitches, tennis courts and basketball pitches were laid for the use of all ranks, aggregating about 50,000 feet super. Because the sun set at about 7 o'clock in the evening, provision of local flood-lighting increased the value of these facilities. An open air cinema at the main camp was reconstructed. In building the tiered amphitheatre, empty cement drums, filled with coral sand and stacked end-on in rows one above the other, proved a cheap and effective method of making retaining walls. The two churches in the main camp were rebuilt by replacing the attap covered sides with stone walling. Coral stone taken direct from the beach produced a very pleasing and appropriate finish. This work on the churches was completed largely by volunteer labour in off duty hours.

Because the ground is so flat and peak periods of rainfall so intensive, drainage was always a major consideration in building construction. Elaborate and extensive soak-pits were required. Due to the increased rate of run-off, asphalt surfaced areas sometimes created a resultant local drainage problem. With heavy rainfall interspersed with long periods of drought, appearances could be very misleading, particularly when differences in level of 1 or 2 feet could be critical. It was important to keep accurate records of local flooding as these occurred so that the cause could be diagnosed and preventative action taken.

Utilities

(A) *Power*

As scientific and base facilities built up, so the requirement for power and light increased greatly. A new power station of eight 300 kilowatt diesel generating units (English Electric 3 phase AC) was built at the main camp. In the interests of speed, effort, and cost, cover was provided by Romney hutting of tubular steelwork covered with aluminium sheeting. The consequent lack of an overhead travelling crane was felt, and portable cranage had to be used for major overhauls of the installed equipment. In base areas, the number of separate power stations was reduced by rationalization to economize in manpower and running costs. Because of the distances involved it was decided to change over from low tension to high tension distribution (3.3 kv) and a start was made on this project towards the end of the year. At the main airfield planning was completed for an underground HT ring main (3.3 kv) of about 4 miles in length, which was subsequently laid in 1959. The high rate of corrosion and earthing as a result of salt in suspension in the air, created a heavy maintenance commitment on electrical distribution lines. In order to keep resultant interference with user supplies to a minimum, circuits were sectionalized to permit local isolation of faulty areas. Stand-by sets were provided at vital points to serve the operating theatre, the airfield control tower and laboratories which required continuous operation.

(B) *Water*

The absence of any readily available fresh water is probably the chief reason why the island remained unoccupied for so long. It may be of interest that fresh water for the American forces throughout their stay was provided entirely from distillation plants. The source of indigenous water on Christmas Island is shallow wells, scooped to a maximum of about 6 feet in depth. These were covered over to reduce the growth of algai and also loss from evaporation. The fresh water layer lies on the top of the salt water-table and in places is only a few inches in depth. The depth of the salt water-table is influenced by tidal movement. It was thus vital to control rigidly the rate of pumping, otherwise the fresh water layer may become contaminated by the intrusion of saline water, resulting from a local lowering of the water-table. Once contaminated it may remain so for months on end. At peak strength the Task Force consumed approximately 500,000 gallons of water a week, the bulk of which was pumped to the user through a piped distribution system (6-inch and 4-inch Victaulic piping). Ground water sources were supplemented by distillation plants since there was a scientific requirement for this type of water. Three vapour compression diesel driven sets were installed during the year (two at 200 GPH, and one at 400 GPH). The salinity of the fresh water sources averaged 50 parts per million which was well within accepted standards. It may be recalled that the salinity of the Tobruk Wells used by the besieged garrison during the last war was of the order of 1,500 parts per million. During the year, as an insurance against drought the principal source of fresh water for the main camp was duplicated by providing an entirely new water point outside the sphere of influence of the original source. This included local storage in the form of Braithwaite bolted steel tanks, each of 25,000 gallon capacity.

(C) *Sewage*

Initially sanitation requirements were provided in the form of Elsan type chemical closets. The effluent was conveyed in special vehicles for disposal by pumping out to sea. Mention has been made of the water-borne sewage system installed for the new hutted camp. Because the ground is so flat and the water-table relatively high, the maximum distance over which gravity drainage was feasible was about 240 feet (fall of 1 in 80). Thus sewage had to be pumped under pressure. The system adopted consisted of an arrangement whereby sullage and sewage gravitated from ablution blocks to a number of primary collecting tanks. From there it was pumped to secondary collecting tanks by automatic controlled (floatless) electric pumps (3 inch). Thence to a main tank from where the sewage was pumped to the outfall, built over the reef at about 2 miles from the camp perimeter. The sewage was untreated and was carried well away from the shore by the littoral drift. All sewage and sullage tanks were built of reinforced concrete suitably tanked, with pumps mounted in a dry sump (Photo 5). The mains were treated asbestos cement piping (6 inch) laid at an average depth of 3 feet.

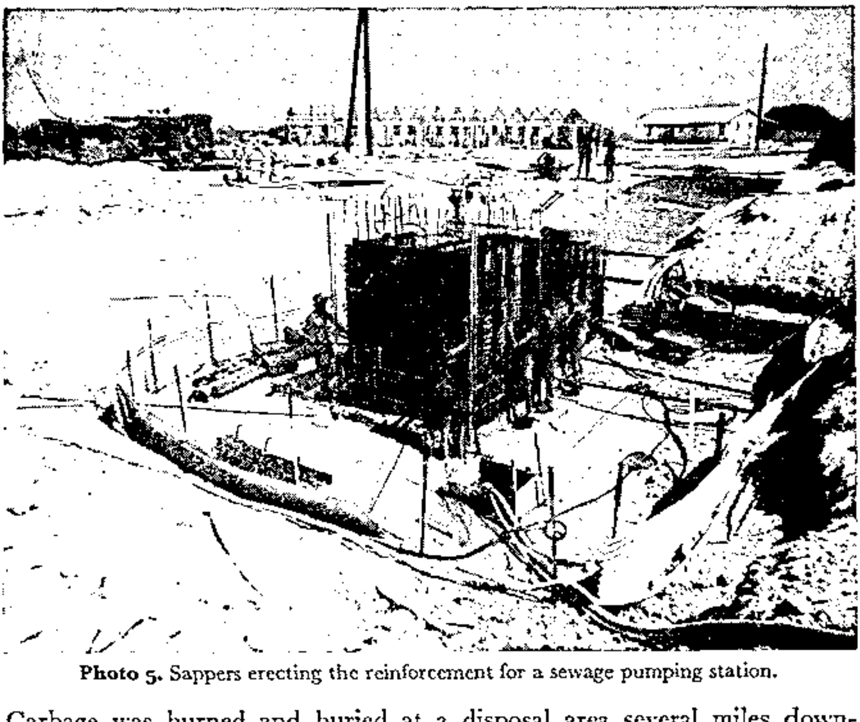


Photo 5. Sappers erecting the reinforcement for a sewage pumping station.

Garbage was burned and buried at a disposal area several miles downwind of the main camp. Operations at this area tied up completely one dragline excavator and one dozer. Flies and insects were kept very much under control by both air and ground spraying of insecticides over a wide area.

(D) *Cold Storage*

Two 50-ton cold stores were erected in the port area in order to economize in refrigeration space afloat, thus reducing shipping requirements. Efficiency was increased by housing each installation inside a structure built of pre-

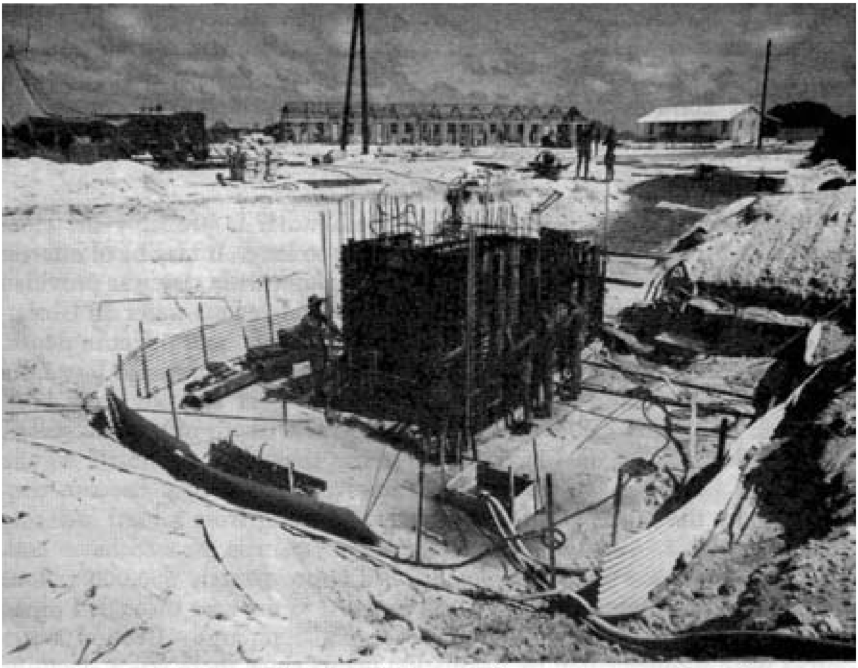


Photo 5. Sappers erecting the reinforcement for a sewage pumping station.

fabricated timber units. One 50-ton cold store could be completed by twelve men within nine weeks.

(E) *Fuel Storage*

In the tank farm adjacent to the port there was a requirement for bolted steel section storage tanks, three stories high, each of 3,000 barrel capacity. On existing tanks local modifications were required to draw off the moisture condensate. Leaks were also a problem throughout the tank farm. These were induced by sprung joints due to settlement or by distortion of the tanks caused by the blast wave of the test explosions. Bostik 1752 proved eventually to be the most satisfactory sealant. A tank including foundations and erection could be completed in nine weeks by a party of eighteen sappers. Victaulic pipes (6-inch) were laid from the wharf side so that fuel could be pumped direct from lighters. With a view to reducing the number of distribution bowsers, the advisability of laying a pipeline from the tank farm to the main airfield was investigated, but the amounts consumed, although considerable, did not justify the cost and effort involved. The construction of POL points on the island with curb side pumps greatly reduced the distribution effort which previously had involved jerrican handling.

Maintenance

In addition to road and airfield maintenance which has already been mentioned, engineer effort had to be devoted to the maintenance of all existing structures and installations. Because of the high rate of corrosion, steel structures required careful watching to maintain protective coatings. The life of corrugated iron sheeting, even when protected, was very limited and it always paid to replace this with corrugated aluminium. This had the added advantage of coolness due to its reflectivity. The higher initial cost was much lessened by the relatively lower shipping freight charge.

Port maintenance included the implementation of both anti-silting and coast erosion measures. The entrance channel into the port had to be dredged regularly both by sea-borne dredger and by dragline excavator operated from the shore. In conjunction with Admiralty Civil Engineers the behaviour of currents and drift was investigated over a period by observing the movements of a variety of coloured stones placed at selected points along the beach. Groynes to counteract coast erosion and consequent silting of the channel were built by using a series of wire gabions. The material was 6-inch mesh fabric which was bent and spot welded to form rectangular baskets. These baskets were secured in position by iron pickets and filled with coral stone. Groynes of this nature can be as effective as pile-driven groynes. They are much quicker to produce and require no plant or skilled labour on the site. Due to the high rate of corrosion and friability of the coral stone their life was limited, but again they were cheap and simple to replace.

Organization

Task Force Grapple

Joint Task Force Grapple comprised four Task Groups (Naval, Army, Air and Scientific), and was commanded by an Air Vice-Marshal. The outline organization is shown diagrammatically in Fig iii. Briefly, the Royal Navy were responsible for logistic support; weather reporting and sea-search; and for sea communication with the adjacent islands of Fanning and Malden. The Royal Air Force, in addition to weather reporting and area search, were responsible for delivery and firing of the weapon; for flying Canberra sorties to take cloud samples after each test explosion; for maintaining regular air communication, using Hastings and Dakota aircraft, with the advanced base at Honolulu, the adjacent islands, with Australia and the United Kingdom; and also for general administration on Christmas Island including the feeding of all troops ashore. The scientific group from the Atomic Weapons Research Establishment at Aldermaston provided the weapon; assembled and tested it; and were responsible also for health physics control, and for recording, collation and assessment of scientific test data.

The Task Force Headquarters included four staffs serving the four Task Groups (Fig iii). It was located in the Air Ministry (except for the scientific staff who were at Aldermaston) and, with the exception of a rear headquarter component, moved to Christmas Island for the duration of each test series. The military staff was headed by a Chief Military Planner (Colonel) who was also Chief Engineer to the Task Force, as well as Commander of the Army Task Group on Christmas Island. In view of the purpose of this paper, for simplicity this officer will be referred to throughout as the Chief Engineer. Unlike the Chief Naval and Air planners, the Chief Engineer was based normally on Christmas Island, and only returned to London for short periods of consultation. His London based staff consisted of two elements; a military logistic staff (under an AA & QMG), which dealt with the provisioning of stores and plant, movement, and personnel matters; and an RE planning team (under a Staff Officer Royal Engineers Grade I), which was responsible for the detailed development of plans for major works projects.

The Army Task Group

(A) *Composition*

The Army Task Group comprised:—

Chief Engineer's Headquarter Staff (Island based)
Headquarters 38 Corps Engineer Regiment
- 48 Field Squadron RE
- 59 Field Squadron RE
- 61 Field Squadron RE
- 63 Field Park Squadron RE

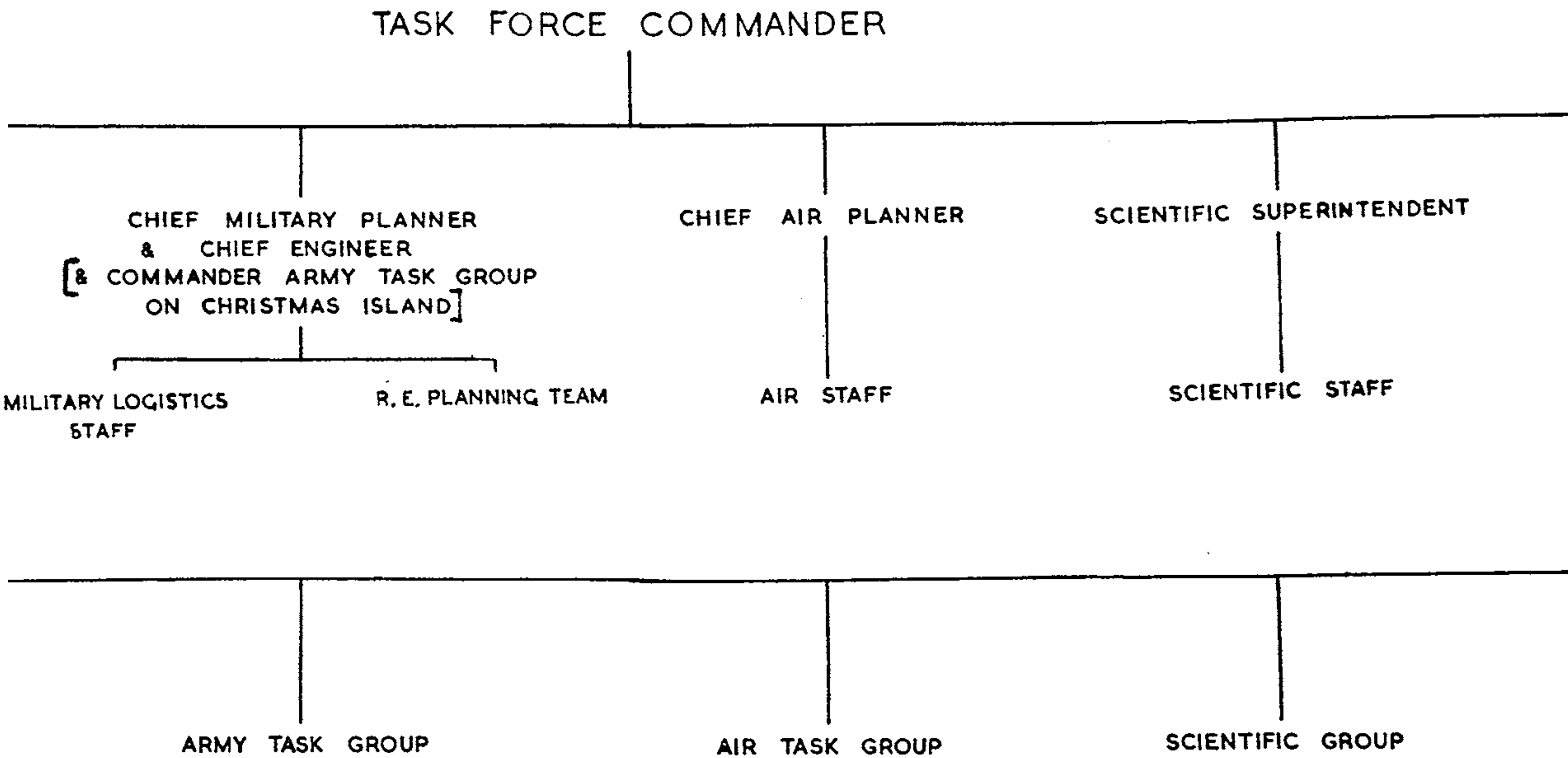
12 Independent Field Squadron RE
73 Christmas Island Squadron RE
Two Construction Troops Fijian Military Forces
One Transportation Troop 51 Port Squadron RE
504 Postal Unit RE
2 Special Air Formation Signal Squadron, Royal Signals
94 Company RASC (Mechanical transport)
RASC Services
RAOC Services
2 Special Engineer Workshops REME

(B) *Role*

The Chief Engineer's Headquarter Staff based on the island consisted of a DAA & QMG and a small works staff comprising an SO2RE (Works), an SO2RE (E & M), an SO3RE (Resources) and an SO3RE (Works). The DAA & QMG was responsible for staff duties concerned with discipline, personnel movement, and administration of the Army Task Group.

TASK FORCE GRAPPLE – OUTLINE ORGANIZATION

FIG III



The Engineer field units listed above, together with the Construction Troops of the Fijian Military Forces, were placed under command of Headquarters 38 Corps Engineer Regiment which was made responsible for the execution of new works projects. The Christmas Island Squadron Royal Engineers, which was organized on an electrical and mechanical basis, was concerned mainly with the operation of utilities, and with the maintenance of completed buildings and installations. The Field Park Squadron which was integral with the Field Regiment, supported all of the sapper units, by providing heavy plant such as earth moving equipment and cranes; workshop facilities; and materials, such as crushed aggregate and prefabricated stores.

The Transportation Troop provided the stevedore organization for unloading sea transports at open anchorage. This activity was controlled by a Port Commandant, a Royal Engineer Major, who was also Staff Officer (Movements) to the Chief Engineer. In transferring cargoes from hold to lighter, and from lighter to wharf, considerable ingenuity was exercised in handling and slinging of awkward loads, some of which weighed up to 25 tons. Whenever feasible, stores were transferred at the wharf from the lighter direct into MT for transporting up country, in order to avoid unnecessary handling. Tonnages handled by the sapper stevedores in 1958 aggregated just over 100,000 shipping tons, excluding fuel and rations.

504 Postal Unit ran the British Forces Post Office 170, which provided both air and sea mail facilities for all personnel in the area. In view of the impact of this service on morale, emphasis was placed on speed and efficiency of operation. Detailed sorting of mail, down to cities and counties in the United Kingdom, was carried out on the island before dispatch; and a close liaison was maintained with all movement staffs to ensure that every available lift was utilized to the full. The introduction for the first time in a Forces Post Office of Post Office Savings Bank facilities proved a popular innovation, and the BFPO also carried out a brisk trade in premium bonds.

The Special Air Formation Signals Squadron laid and maintained line communications on an island basis, including control cables for scientific use. Royal Signals personnel were trained to operate a wheeled grader and a mechanical trencher, thus economizing in the Royal Engineer support required. Reduction in signal operating personnel was achieved by combining certain telephone exchanges. The life of signal electronic equipment was increased substantially by introducing air-conditioning. The load on signals communications generally was restricted by emphasis on signal discipline.

94 Company RASC was organized as a headquarter platoon and three transport platoons. The headquarter platoon operated a twenty-four hour service at POL points, and also distributed Dieso and oils to the numerous working sites. One transport platoon was absorbed almost entirely on port clearance working on a two shift basis. The other two platoons operated tipper lorries (10-ton) in close support of the sapper field units, with whom they formed a strong association. The unit was provided by War Office in 1958 at the request of the Chief Engineer in order to relieve RE units of the task of manning and operating load carriers not integral with the unit, thus enabling the maximum number of sappers to be employed on constructional work. As a result of a drive on maintenance by the unit, availability of MT increased from 60 to over 90 per cent. During its year on the island this unit covered about 900,000 miles carrying about 1¼ million tons.

The RASC services, in addition to manning the DUKWS, ran a field bakery which provided up to 6,000 pounds of fresh bread a day for all personnel ashore and afloat. DUKWS were used to supplement lighters for ferrying certain stores ashore from the Christmas Island deep-water anchorage. They were also of great value in running stores ashore to Task Force detachments on the islands of Malden and Fanning. At times their drivers displayed considerable skill and courage in manipulating the heavy swell. DUKWS were particularly useful in avoiding double handling, and were proved to be more suitable than any other vehicle for carrying fragile stores, delicate instruments and explosives over rough ground. By fitting an A frame on the stern, loads of up to 5,000 pounds could be loaded with the vehicle winch, care being taken to have sufficient ballast in the bow as a counterweight. Regular servicing was essential, and the hulls had to be painted periodically with red oxide to counteract corrosion.

The RAOC services ran an Ordnance Field Park which provided common user stores and spares. They also operated a field laundry for the island and this laundered some 30,000 sheets a week as well as articles of personal clothing. Steam presses were installed to process tropical green uniforms. Because a field laundry does not usually include this type of plant, the operators had to be trained locally. The load on the laundry was kept to an acceptable level by virtue of working dress being normally a uniform hat (with badges of rank sewn on), a pair of shorts, boots and short puttees. This pattern of dress had the additional advantage of ensuring that skin diseases were kept well under control.

The Special Engineer Regiment Workshop REME supported the Task Force most ably by carrying out repairs beyond unit resources on vehicles and engineering plant. On one occasion a large gear wheel of seventy teeth on a vital plant was stripped as a result of a clutch failure. REME artificers, working on a continuous shift basis, built up the wheel by metal spraying, machined the teeth, and had the plant in operation again within 72 hours. Several light aid detachments from this Workshop were deployed at selected sites where there were particularly heavy plant or vehicle concentrations. In all the Army Task Group operated some 200 vehicles and 300 major items of mobile plant.

Planning

Distribution of Load

The bulk of the planning of preparatory engineer work required for each test was carried out on the island. There were two main reasons for this. The time factor was acute; and secondly, the design was linked closely with local operational, scientific and topographical considerations. On the other hand, as much as possible of detailed planning on the longer term requirements, such as development of the base, was done in London. Members of the RE Planning Team visited the island as required, when agreement was reached with all concerned on the first key plan of a particular project. Then back in England plans were developed by the team, in consultation with the appropriate authorities (eg financial, medical, etc). It was important to lay down check points at which partially developed plans were re-submitted to the island for a check on local implications.

Financial Cover

In spite of the extreme urgency, and the importance of these trials from a national point of view, all of the engineer work had to be accurately costed.

Quite rightly too, the validity of estimates had to be well proven, and justification for expenditure fully explained. On occasions the Chief Engineer attended meetings with Treasury and Ministry of Supply financial representatives and stated his case. It is only fair to record that requests for financial cover were always given sympathetic and realistic consideration.

Priorities

Because time was at such a premium, it was obviously essential to establish clearly defined priorities. The desirable had to be segregated ruthlessly from the essential. The priority of any particular project could usually only be determined in consultation with the other Services at Chief Engineer level.

Requirement Investigation

Before planning began it was necessary to ensure that the requirement was defined correctly by the user. This critical examination was usually conducted by asking the user not "what do you want?" but "what do you want to do?" The user will often have strong convictions on what he wants, but, unless a preliminary joint exercise is carried out on the lines suggested, the final product may be surprisingly disappointing from the user's point of view. This investigation should result not only in the requirement being met with the minimum effort, but also in a satisfied customer. Another factor worth considering at this stage was the possibility of future development.

Planning Plan

The planning plan was then formulated, and this included target dates for the various stages of design, procurement, and execution. There was sometimes a tendency to place undue emphasis on the projected date of start of work on the ground. It is by no means certain that the job which starts first will finish first. The aim was to complete the job in time with the least expenditure of resources. High utilization of all available plant was essential.

Flexibility

During planning it was important to maintain an element of flexibility. However much finality was achieved in the initial definition of the requirement, changes during planning were liable to be proposed by the planners as well as by the users. Field-Marshal Lord Alanbrooke wrote in his published *War Diaries* "so few people ever realize the infinite difficulty of maintaining an objective or a plan and refusing to be driven off it by other people for thousands of good reasons." The engineer is well aware of the thousands of good reasons often put forward in support of second thoughts, after planning is well in hand or even after work on the ground is well advanced. Clearly a major consideration was the impact of a suggested change both on the date of completion, as well as on the efficiency of operation of the final product. Exceptionally a relatively major change may be capable of being implemented with a very small additional effort, which is out of all proportion to the value that will accrue. More generally, however, a change in plan as a result of second thoughts leads only to delay and frustration. A vital consideration always was the possible effect of a proposed change on the morale of hard pressed planning staffs and on units executing the work. Obviously changes which constituted refinements or frills were resisted strongly. The best is indeed the enemy of the good.

Rationalization

Considerable economy in time and effort was achieved by rationalization as far as possible of user requirements for such items as laboratories; technical and storage facilities; offices; and messes. For timber framed construction, standard wooden trusses and wall frames were prefabricated locally in the RE Workshops, and later specially designed timber hutting was prefabricated in the United Kingdom. A degree of standardization on steel framed buildings was achieved eventually by using Conder steel shedding units. This rationalization not only reduced the planning effort substantially but also the erection time on the site. Prefabrication had the further merit of reducing the number of skilled workmen required to assemble the structure.

Work Study

Within the limitations of the time available, work study techniques were employed to devise the best means of execution. As is well known, work study is a very old and well tried tool of management the basis of which is detailed analysis, scientific reasoning and, above all, a common-sense approach to psychological implications. Highly repetitive work such as the erection of prefabricated sections was organized in phased construction by locally trained specialist teams. Simple alignment aids designed for the assembly of complicated plant and structures saved much time. Realistic yardsticks of production were evolved and this inspired a healthy competitive spirit between working parties.

Site Organization

Detailed pre-planning of each work site was the only way of avoiding waiting time for either plant or labour, both of which were at a premium. The aim was to complete the setting out and the optimum layout of initial stores before working parties arrived on the site. Maximum use was made of mechanical aids during construction. RAF mobile platform equipment which can be adjusted pneumatically, was invaluable for high building work. Safety precautions during construction were enforced strictly, and, in spite of the intense activity, the accident rate was negligible.

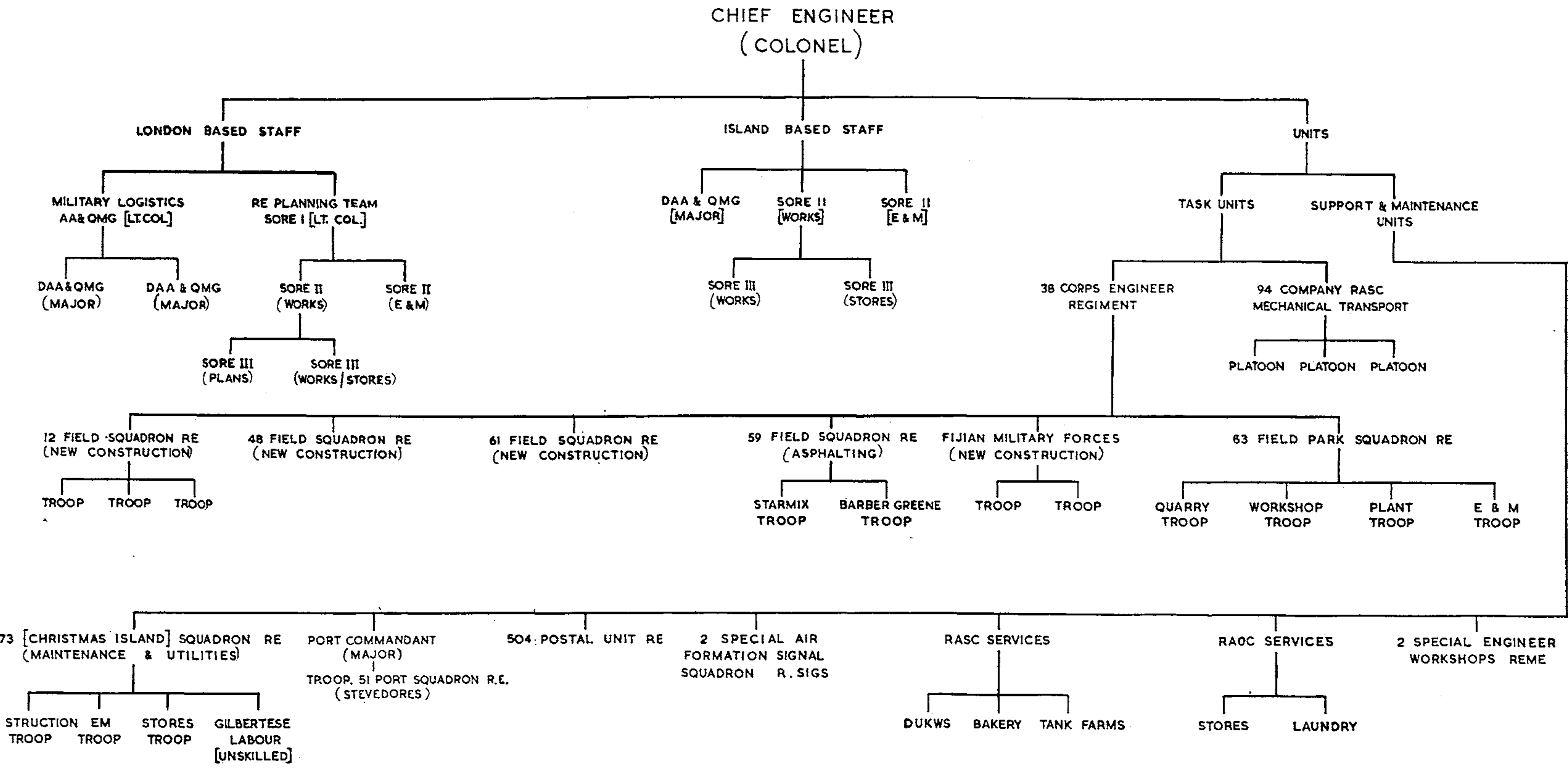
Control and Supervision

Command Structure

The organizational command structure is shown diagrammatically in Fig. iv. Task directives were issued for each test by the Chief Engineer to the engineer regiment (for new construction work) and to the other units under his command (for support operations). The engineer regiment set up a works office under the second-in-command to control new construction. Being relieved of many of his more normal duties because of the Royal Air Force's responsibility for day-to-day administration, the second-in-command was fortuitously in a position to assume this fairly onerous commitment. This works office allocated new construction work to engineer units under command of the regiment, and allotted plant, equipment, and transport to them. It also controlled priorities for demands from these units on the Field Park Workshops (for prefabricated stores, etc) and on the REME Workshops (for major repairs to plant and vehicles). The basic principle of allocating work was to retain the command structure of the units available. Thus individual tasks were allotted as far as possible on a squadron or troop basis. Occa-

ORGANIZATIONAL COMMAND STRUCTURE – ARMY TASK GROUP GRAPPLE

FIG. IV



sionally, small adjustments had sometimes to be made between organic units by temporary reinforcement for a particular task in certain skilled trades. This was done exceptionally, and understandably, was never popular either with the units lending these men or with the men themselves. With the extreme shortage of such trades as surveyors, refrigeration mechanics, and plumbers, it was at times inevitable. Requests from scientific groups for specific types of tradesmen were discouraged, as this could only have resulted in an unacceptable dispersion of effort. Instead, details of the particular requirement were obtained from the scientists and responsibility for meeting this was then allocated to an appropriate squadron or troop commander. This system worked well, and relationships with the scientists were excellent. A small pool of Clerk of Works (Constructional, Mechanical and Electrical) were allocated to field squadrons according to the type of work in hand. Again, in the interests of human relationships, every effort was made to keep these Clerk of Works associated throughout the operation with the same squadron as far as possible.

Briefing

Working drawings, specifications, stores lists, and technical instructions were issued, as appropriate, by Chief Engineer's island staff to the unit concerned well in advance of the start of work. These were supplemented by verbal briefings as necessary, and by site consultation throughout the execution of the work. In relation to timing, the Chief Engineer, wherever possible, laid down only the date by which a task had to be completed; leaving the choice of the order in which tasks were done and their starting dates to the unit concerned.

Communication

Reference has already been made to the Chief Engineer making short visits to London for consultation. He did this on two occasions, for consultation with the Task Force Commander and for conferences at Air Ministry and at Aldermaston. On one occasion he returned to the island within ten days of having left it, having had a full week of rewarding consultations and discussions in England, which is a tribute to the efficiency and comfort of long distance air travel. Weekly progress signals on engineer work, and also monthly detailed reports were sent to Air Ministry throughout the year. These were scrutinized by Chief Engineer's London staff. In addition the Chief Engineer and his London staff were in daily communication by cable, and this was supplemented by teleprinter conversation when the occasion demanded. Members of the London staff visited the island from time to time for briefing by and consultation with the Chief Engineer.

Progressing of Work

A master progress chart of all work in hand was maintained at the island headquarters of the Chief Engineer. Information and progress on individual projects was fed into this headquarters from the works office run by the regiment, and from the headquarters of the other army units directly under command of the Chief Engineer. The Chief Engineer held works progress meetings once a week with his sapper commanders, and a monthly coordinating conference with commanders of all units in the Army Task Group. Representatives of the other three task groups attended these meetings, as clearly the closest inter-service liaison was essential.

Technical Supervision

The Chief Engineer was both the consultant as well as the main contractor to the Task Force. This dual responsibility, which is foreign to civilian practice, can work extremely well in the military engineering sphere. The author hastens to add that he does not suggest the extension of this principle in the civilian engineering world. The conditions are, of course, quite different. It may be of passing interest that engineer work in support of the American nuclear tests at Eniwetok was carried out entirely by specialist civilian contractors. In his role as a contractor, the sanctions payable for failure were perhaps more severe than would be the case with a civilian contractor.

This dual responsibility was reflected through the various control levels at least down to the RE Clerks of Works, whose contribution to good workmanship was well up to their traditionally high standards. It is basically a question of a high sense of loyalty and responsibility; and of pride in a job well done. To their credit the sapper tradesmen displayed much personal pride in individual standards of workmanship. The incentive was, of course, exceptional. Units knew they were engaged in work of national importance. The conditions of isolation together with the acute time factor presented a tremendous challenge to all ranks which met with an enthusiastic response. The scientific or technical necessity for particular tasks and the precision demanded was explained to working parties, and, wherever possible, scientists briefed units on how their work contributed to the joint operation.

Methods of technical check were normal. The Chief Engineer and his senior engineer commanders spent much of their time visiting works sites. Rigid performance tests on installed equipment were carried out in the presence of the user. Independent checks were made on setting out, particularly where high accuracy was essential. Quality control of concreting and asphalting operations was assisted by a soils laboratory, the staff of which consisted of a Staff Sergeant and three assistants. The test equipment included a mobile CBR machine; block crushing and workability test apparatus for concrete, and marshal test apparatus and other analysis equipment for asphalting operations.

Stores Control

A central stores depot organization (CESD) was set up to receive, unpack, identify, record, hold and issue imported stores. It was clearly important to avoid tying up an undue proportion of manpower in the stores organization. With this in view, attention was directed primarily to methods of dispatch of stores from their place of origin. Where feasible, limitations were imposed on the maximum weight and size of individual bundles. Packaging was reviewed both to ensure adequate climatic and handling protection, as well as to reduce time spent on the island in segregating individual items. Insistence on readily identifiable markings paid large dividends, since identification of the wide variety and complexity of imported stores could be very time consuming. Attention was also paid to planning of stores handling. Wherever practicable stores loaded at the port from lighters into MT were transported direct to working sites to avoid unnecessary handling. Dumps of material in bulk were built up at strategic points easily accessible to working sites, for such items as UK prefabricated hutting units, cement and bitumen.

Control of stores was maintained direct from Chief Engineer's headquarters. Strict observance of accounting procedures in the CESD was essential since most of the stores had been provisioned for specific projects. Apart from the question of finance, which was always of prime consideration, there was neither the shipping space nor the manpower handling capacity on the island to permit the establishment of generous reserves. Policy on stores control varied necessarily with the emergence of new operational requirements, with unforeseen changes in shipping programmes, and with the ability to economize in stores in short supply by the use of substitute materials. With regard to the issue of stores, officers in charge of working sites dealt direct with the Chief Engineer's stores staff. Each troop commander usually appointed an NCO in charge of project stores as a link between his troop, CE stores staff, and the staff of the CESD.

Finally on the question of stores, the Chief Engineer was given fairly wide powers of local purchase in Honolulu. These powers were only used exceptionally. It was a particularly valuable authority as it enabled limited use to be made of the considerable local light engineering industry in Hawaii for the prefabrication of certain small items (eg special ducting). As dollar expenditure was involved there had always to be a sound reason why these stores could not have been procured through other channels. An RAF local purchase officer on the strength of the Task Force detachment at Honolulu acted as agent for the Chief Engineer in negotiating purchases.

Key Engineer Activities

Crushed Aggregate Production

A limiting factor on the rate of laying of the considerable quantities of asphalt surfacing was the production of crushed coral aggregate. A beach quarry was established in the autumn of 1957 on the windward side of the island near the north-east point. There a natural bed of coral slab extends for several miles along the beach, above the high water mark, at an average width of 40 yards and to a depth of about 3 feet. The slabs are plate-shaped and average about 2 feet in width, with a maximum width of about 4 feet. Early in 1958 an *ad hoc* quarry troop was formed of one officer and eighty-three other ranks under command of the Field Park Squadron. This troop operated four Parker mobile crushing and screening plants, mounted on concrete foundations. The following subsidiary plant was required:—

19 RB	4
BK 50	2
8-yard scraper	1
D7 with winch	1
D4 with winch	1
Size 2 Dozer	4

The coral slabs were conveyed to the crushers by the 19 RB face-shovels from stockpiles maintained by the bulldozers. The rated output of each crusher was 6–36 tons per hour depending upon the feed, screen sizes, and the jaw settings.

Because of the plate-shape of the stone and its friability, the coral slabs had a marked tendency to break along planes of minimum section. In the result much of the crushed aggregate was in elongated shapes which did not conform to any accepted grading specification. The nominal 1½ inch aggregate of splinter-shape could have a maximum dimension of 2½ inches and still pass the 1½-inch sieve. Perhaps a rotary hammer type of crusher would have produced less elongated aggregate. For the production of aggregate for the asphalting plant, screens were set as follows:—

	Screen Size	Stone Size	Approximate density in tons per cubic yard
Coarse	1⅝ in sq plate	⅞ × 1½ in	0.83
Medium	⅞ in sq plate	¼ × ¾ in	0.87
Fine	¼ in sq mesh	less than ¼ in	0.96

The densities given above were obtained from a series of volume batching measurements. With these screen sizes and the settings of primary and secondary jaws of the order of 1⅛ inch and ¼ inch shim respectively, the proportions by weight of crushed aggregate averaged:—

Coarse	32–25 per cent
Medium	40–39 per cent
Fine	28–36 per cent

Although there was an excess of fines, there was a particular deficiency in material passing the smaller sieves.

Both primary and secondary jaw units stood up well to intensive operation, and wear was negligible. Dorman engines gave satisfactory service, and no overheating occurred although normal operating temperature was about 200°F. Due to the prevalence of dust, filters had to be changed every 250 hours and ancillaries were removed and engines decoked every 1,500 hours. Abrasive dust and salt in suspension in the air combined with the high ambient temperature caused excessive wear on belts, with consequent shredding and stretching. It was not uncommon for the rate of replacement of a set of belts to average only one month per crusher. Chains wore well provided they were kept properly adjusted. The reciprocating feeders were a source of trouble, principally because of the widely differing sizes of stone fed to the machines. At a subsidiary quarry where the coastal ridge was sufficiently high to enable a chinaman to be built, a gravity feed system worked very satisfactorily. In damp conditions, the ¼-inch square wire mesh screens clogged considerably, with the result that fines were carried over and adulterated the medium sized aggregate. Clogging due to damp was noticeable also in the main shute, and on the 1-inch Niagara square mesh by-pass screens, thus slowing up the flow of stone. This damp occurred both as a result of rainfall and when the coral bed had been worked down to the level of the water-table. To cope with the impact of stone on the reject shutes additional plates had to be welded on for strengthening.

The training of operators was relatively simple, and a vital part of their task was meticulous attention to daily and weekly greasing schedules and to oil changes. Fitters were key personnel, and it was found that a good fitter required about three weeks to familiarize himself thoroughly with the idiosyncrasies of particular crushers. A battery of four crushers were normally in use, three being in operation, and one under overhaul or as a stand-by. Two shift working was normal, and a maximum output of 1,400 tons of crushed aggregate per day was finally achieved. This figure was just adequate to meet the requirement for roads, airfields and building construction work.

Asphalt Mix Production

Crushed aggregate was conveyed by 10-ton tippers from the main quarry to stockpiles at the Parker Starmix 40 plant located about 3 miles away, near the main airfield. Again, the rate of production of bitumen mix dictated the rate of laying of asphalt surfaces by the Barber-Greene layers, which were never extended for any appreciable length of time to their full laying capacity. This Starmix 40 plant was assembled at the end of 1957, and was in operation from January 1958. The plant consisted of:—

(*a*) Aggregate feed hoppers and elevators.

(*b*) Drying unit with burner equipment, exhaust fan and cyclone dust extractor.

(*c*) Parker oscillex double deck screens, four compartment storage hopper, weigh-batch hopper, bitumen supply and paddle mixer.

(*d*) Pneumatically operated controls (from a central control panel).

(*e*) Filler elevator.

(*f*) Power unit Dorman diesel engine (140 bhp at 14,000 rpm).

A working party of one officer and twenty-eight other ranks was required to operate two shift working. Subsidiary plant comprised:—

One 19 RB crane
One Loraine crane
One Size 2 dozer
Two 1 cubic yard dumpers

In addition a party of twenty-six other ranks was needed to operate the bitumen heating tank farm to support the starmix plant. Equipment consisted of:—

Nine bitumen kettles (1,000 gallon)
Three bowsers (1,000 gallon)
One jumbo crane
One matbro fork lift truck

The equipment used to operate this bitumen heating tank farm was by no means ideal, but it was the only equipment available on the island at the time. The large number of small units was clearly uneconomical in manpower. Later in 1959 a more efficient system was introduced based on a modified 5,000 gallon self-heating munistatic tank. Bitumen used was Shell 60/70 PEN supplied from the United Kingdom in 36-gallon containers.

Typical mixes produced by the plant were as follows:—

(*a*) Levelling course. The grading specification is shown in Fig v. The binder was 5 per cent by weight and there was no filler.

(*b*) Binder course. The grading specification is shown in Fig vi. The binder was 6 per cent by weight, and cement was used as a filler at 2.7 per cent by weight.

(*c*) Sand carpet (for tennis court surfacing). Fines (passing a $\frac{3}{16}$-inch sieve) were used as supplied from the island quarry. The binder was 7½ per cent by weight and there was no filler.

Owing to the high moisture content of the coral aggregate which was never less than 10 per cent, the output of the starmix dryer proved inadequate. This was increased to a satisfactory level by blowing compressed air into the dryer, and by stepping up the fuel oil heating capacity correspondingly. The total output from this plant from January to October 1958 was of the order of 65,000 tons of asphalt mix in about 2,400 engine hours. The maximum daily output achieved was 690 tons with two shift working.

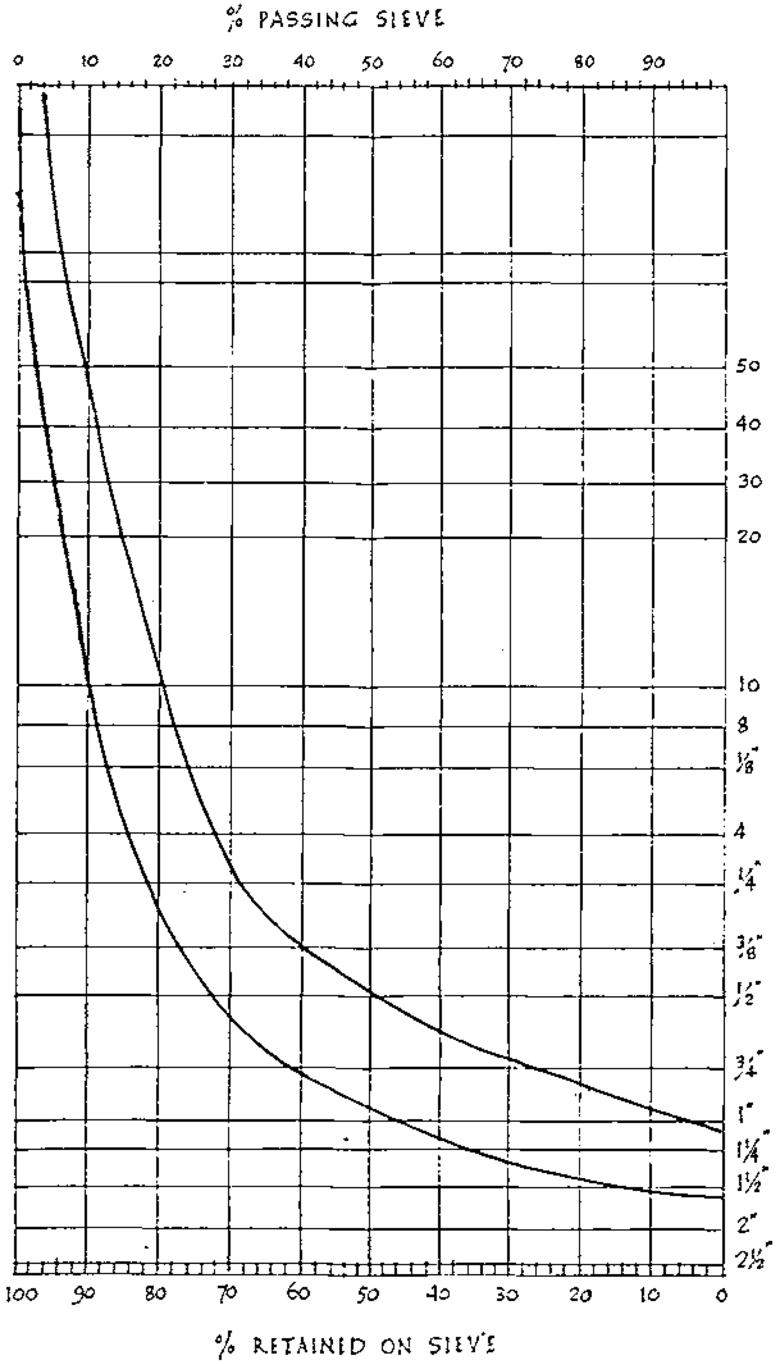
Originally operators for this plant were trained in England. Subsequently reliefs were trained *ab initio* on the island, and, on balance, this local training was preferable. Within a period of six weeks sapper teams to operate both the starmix plant and the Barber-Greene layers could be trained to adequate standards. Again the inclusion in the working force of a good fitter was mandatory, to advise on preventative maintenance and to carry out timely minor repairs. A major breakdown occurred due to an error in operation of the control panel which resulted in two batches being dropped into the paddle mixer. Although the shear pins sheared successfully, because of their positions the momentum of the oscillex screens forced the mixer to carry on turning with the result that the paddle shaft was bent. This would not have occurred had the shear pins been located in either the driving or the driven wheel of the pug mill drive. To avoid a recurrence in operator error, a local modification was carried out on the control panel which tended to ensure, by a form of mechanical interlock, that the controls were operated in the correct sequence. Another major breakdown resulted in the shearing of teeth in the main driver and in the triplex chain wheel due to lack of lubrication. This was caused by the belt to the oil pump drive being wrongly replaced after adjustment, as a straight instead of a cross drive. Thus the direction of the pump was reversed, causing lubrication failure. A directional arrow stamped on the pump pulley drive might have avoided this reversal of rotation. In all over twenty modifications were suggested to the manufacturer as a result of experience gained. On the whole, this plant stood up extremely well to the exacting conditions of its operation.

Concreting

Concrete construction using coral aggregate was employed extensively by the United States during the war in the Pacific. Experience, based largely on experiments conducted in the Marshal Islands, indicated that coral stone located on the windward side of coral atolls is the preferable source. The resultant aggregate has a higher average specific gravity and a lower percentage of absorption than that from other sources. Typical grading curves for coarse and fine aggregate produced from the Christmas Island quarry are shown in Fig vii. This aggregate was used for all concrete construction, except low grade concrete work. For the latter suitable deposits of natural gravel of reasonable grading were located above the high water mark. Natural coral sand was generally clean and fairly sharp. The characteristics of the standard mixes employed were as follows:—

Grade	Water/cement ratio	Mix proportions: Ordinary Portland cement	Mix proportions: Fine dust sand	Mix proportions: Coral crusher reject sand	Mix proportions: Coarse coral aggregate	Minimum Strength at 28 days (psi)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
I	0.50	1	2.00	1.44	1.56	3,500
II	0.55	1	2.20	1.58	1.72	2,500
III	0.82 to 0.87	1	5.5 (All-in aggregate from selected borrow pits)			1,500

FIG. V.



2" - 2½" LEVELING COURSE
GRADING SPECIFICATION

As was to be expected with the high ambient temperature, the rate of gain in strength after laying was relatively higher than is the case in cooler climates. The maximum strength at 28 days recorded on 6-inch test cubes was 5,000 pounds per square inch. The test cubes failed through crushing of the coral aggregate. Due to the friability of the coral stone, the resultant concrete had a relatively low resistance to abrasion.

Portland cement was imported from the United Kingdom in 400-pound drums. These were robust, and were easy to handle and stack. Because of the high humidity, cement exposed to the air for any length of time in elevator buckets or in hoppers soon became unserviceable due to moisture absorption. Thus the opening of cement drums had to be synchronized with the rate of production of the concrete mix. Packaging the cement in tough waterproof bags of about a quarter the capacity of the drum would have eliminated the time-consuming operation of opening the drums. Bagged cement would however have resulted in greater wastage in transit when deep stowed, and unless it had been dispatched in palatized loads the handling effort on stevedores would have been prohibitive. As always, proper vibration of the concrete was essential for high quality results. Poker vibrators (2-inch diameter) were used widely for reinforced concrete work. Kwikform metal formwork was generally employed for shuttering. It was extremely adaptable, easy to erect with unskilled labour and well suited to high precision work. When tanking of floors and walls was required a single layer of PBS, overlapped and sealed at the joints, was laid on a brushed coat of bitumen over the concrete surface, and then a further brushed coat of bitumen was placed on top. Concrete was laid at a rate of 40 cubic yards per day at individual sites in two shift working.

Building Construction

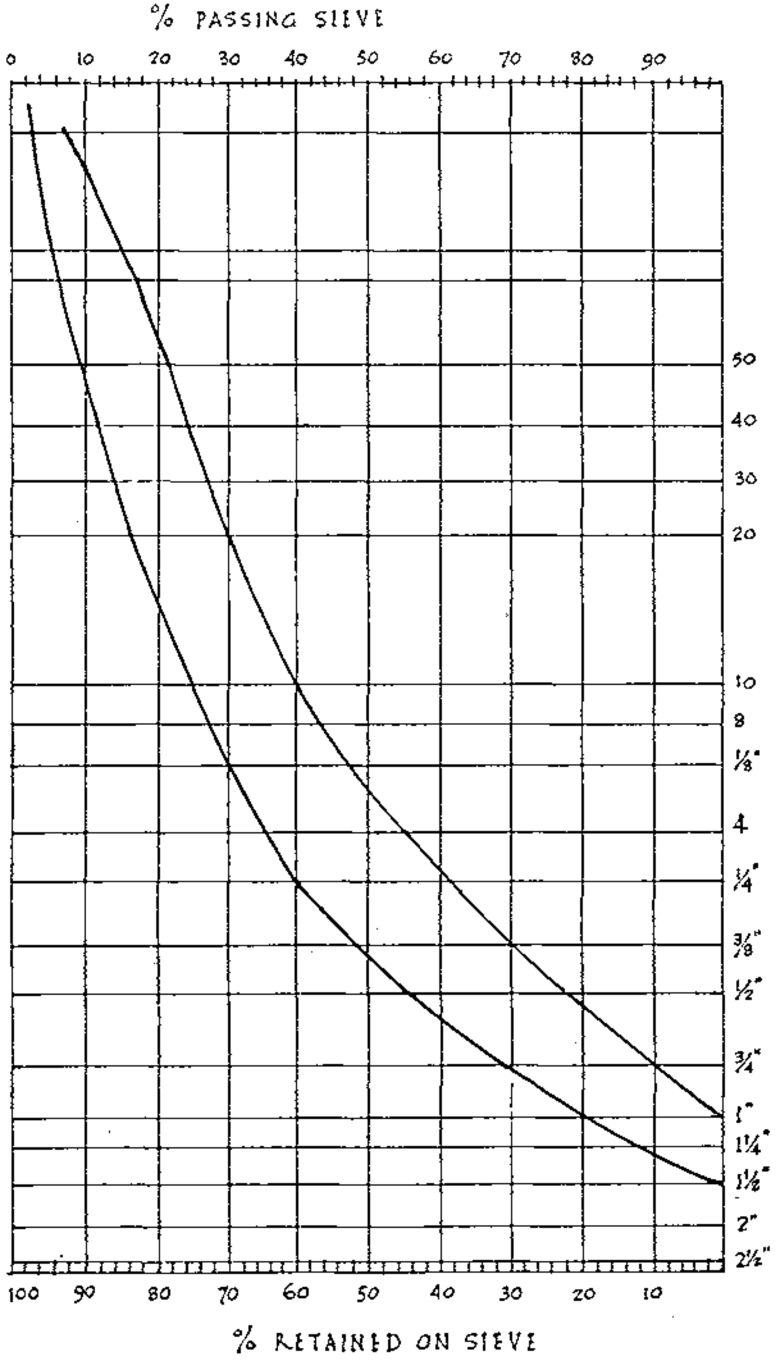
(A) *Timber Framed*

Components for a standard design of timber frame hutting were manufactured in the RE Workshops on the island. This standard design afforded two widths of roof span (24 and 19 feet), and the truss was fabricated in two halves for assembly on the site. The timber wall frames were manufactured in 8-foot sections. Trusses, wall panels and gable ends were prefabricated by means of jigs on mass production lines. This design proved particularly adaptable for meeting requirements for laboratories, communal mess buildings, cook-houses and stores. After a short period of training a troop of the Fijian Military Forces could assemble a hut of this nature of 2,000 feet super complete with aluminium sheet cladding in three weeks.

In view of the quantities required for the main camp project, timber huts were later prefabricated in the United Kingdom and shipped to the island. In common with the local prefabricated hutting, the design was based on an applied 8-feet module of length, and the structure had to be capable of taking the following conditions of loading:—

Maximum wind velocity:	80 mph
Imposed roof load: (truss had to be capable of taking a suspended load of 100 pounds at any point)	15 pounds per square foot
Imposed floor load:	40 pounds per square foot

FIG. VI.



2" BINDER COURSE
GRADING SPECIFICATION

Timber jointing and ironmongery were to the appropriate BS standards. The roof pitch was 22½ degrees and allowance was made for a 3-foot overhang on one side, and a 6-foot wide covered veranda on the other. Windows were of the sun sash louvred pattern. A clause in the prefabrication contract called for trial erection at the contractors' works of three bays and one end section of each type from components selected by the inspecting officer.

(B) *Steel Framed*

Initally requirements for buildings of large span were met mainly by erecting steel-framed equipment disposal sheds (EDD) of 50-feet span. The steel work for these sheds had been used previously in England and erection difficulties were increased by distortion as a result of damage during dismantling and transit. The construction of one shed (150 × 50 feet) complete with cladding and concrete floor absorbed one troop for six weeks. A Bellman hangar (portal frame lattice steelwork) of more than double this area (approximately 16,000 feet super) was built by one troop in ten weeks. When cladding steel framework with aluminium sheeting, it was important to avoid direct contact between the sheeting and the steel ribs or purlins. Otherwise electrolytic action arising from the high humidity and the amount of salt in suspension in the air soon resulted in erosion of the aluminium.

Later in the year demands for buildings in steel framing were met by standardization on the Conder type of shed, the steelwork for which was prefabricated in England by the Condor Engineering Company Ltd, Winchester. These sheds were erected in 15-feet bays of 50-feet clear span (Photo 6). Height to eaves level varied from 12 to 20 feet. This variety of eaves height afforded much flexibility in meeting user requirements, and the portal frame design allowed maximum clear span for stacking or other use. Conder shedding was economical in terms of both cost and erection time. Because the number of separate components is small, assembly was relatively simple. Building time was about a quarter of that required for an EDD shed of equivalent size. A new Junior Ranks Club which consisted of a restaurant, tavern and junior NCOs club was basically Conder shedding adapted by local design (Photo 7). These JRC buildings aggregating over 25,000 feet super were ready for occupation within eight weeks from the start of the work on the ground.

Damage Control

Organization

For each test, the Chief Engineer set up a Damage Control Organization to take protective and remedial action covering medical, radiological, fire and blast damage measures. During the firing phase he operated a Damage Control Headquarters at the Joint Operations Centre on the island. In this Headquarters the following cells were included: monitoring, medical, fire fighting, engineer reconnaissance and engineer rehabilitation. The function of this Headquarters was to:—

(*a*) Record the immediate physical effects of the explosion.

(*b*) To deploy stand-by parties to take remedial action as required.

Both radio and line communications were used to control these activities.

In consultation with the other Services, installations, buildings and essential utilities were categorized beforehand in accordance with their particular function. This ensured that post-firing remedial action was taken strictly

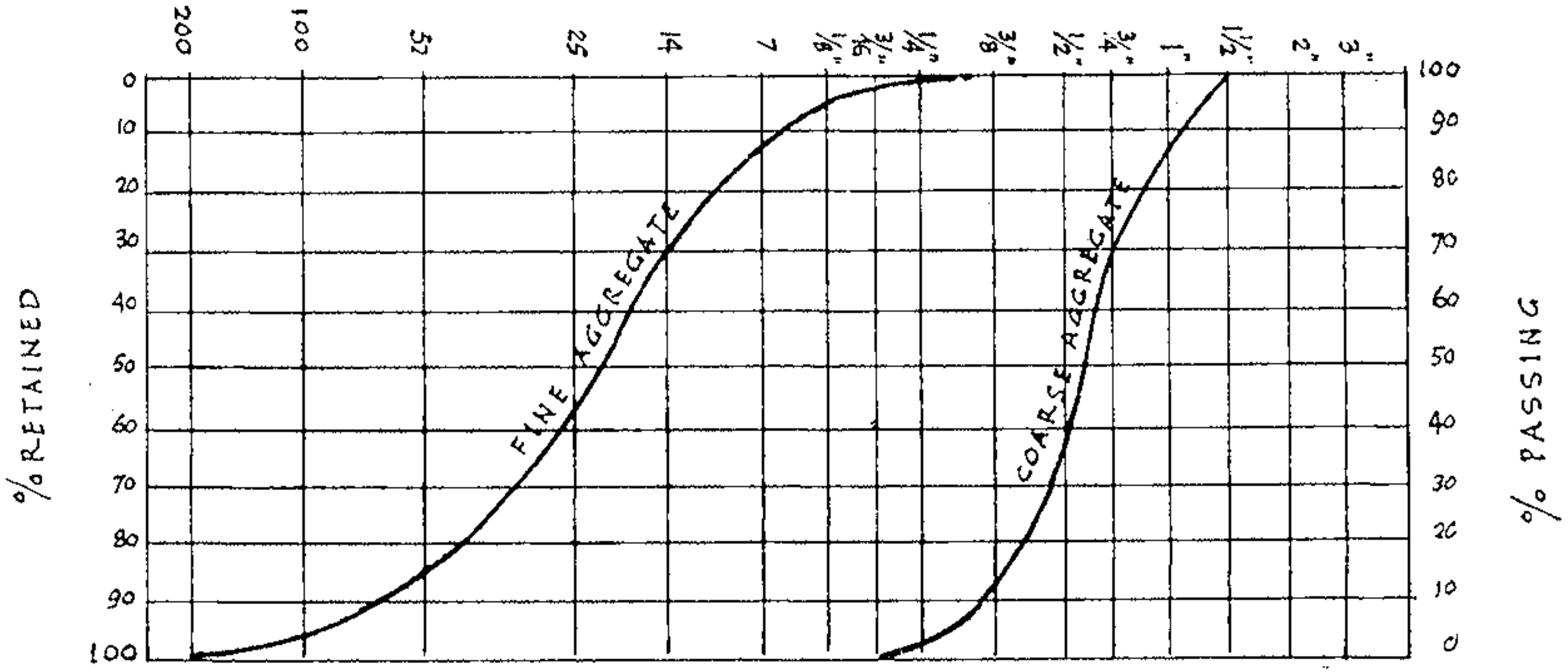


FIG. VII. - TYPICAL GRADING CURVES FOR COARSE AND FINE AGGREGATES.

in accordance with operational priorities. High priority requirements included communications connected with personnel or aircraft safety; essential medical and messing services; and scientific facilities on which the success of the test depended.

Personnel Safety

A comprehensive Personnel Safety Plan was implemented by the Joint Task Force Headquarters to cover all eventualities. In addition to operational rehearsals for scientific reasons, rehearsals of the safety plan were clearly essential. Area Commanders, appointed beforehand from the Services, were responsible for deployment, accounting, and safety of their men under direction from the Joint Operations Centre. The Gilbertese population was evacuated from the island each time. This was a universally popular exercise for the entire village, and the Gilbertese much enjoyed the film shows arranged for them by the Royal Navy whilst afloat. Clearly everyone on the island had to be within hearing distance of the count-down and the count-up, which was relayed over a tannoy system set up for the occasion. Flash protective clothing was worn as required (Photo 8). At the time of burst all personnel had their backs to ground zero, with eyes covered to avoid flash damage to the retina of the eye. Subsequently personnel were warned to brace themselves for the blast waves. Re-entry into possible contaminated areas was controlled strictly, and was always preceded by scientific monitoring teams. There were no personnel casualties as a result of any test explosion.

Fire Damage

The immediate target area was isolated by dozing a fire lane across the island. Stores, equipment and plant, in which induced fires were liable to start, were redeployed or suitably screened. All electrical circuits not in use were isolated. Fire fighting equipment was deployed at strategic locations such as petrol points and tank farms, and fire fighting parties were held in readiness to be directed to affected areas by Damage Control Headquarters. In the event, no difficulty was experienced in keeping induced fires under control in occupied areas. A feature of area bush fires was the ferocity with which the luscious green vegetation burned once a fire was started. In preventing such fires from spreading to occupied areas, air reconnaissance by helicopter was invaluable.

Blast Damage

Clearly the most economical method of avoiding blast damage to buildings and installations was to take this factor into account at the design stage. A few key buildings were made blast-proof by building them in concrete. Siting a building end-on to the explosion could reduce the consequent blast effect. A number of high priority buildings, such as weapon assembly sheds and laboratories, were designed so that panels could be removed just before the time of burst and then quickly reinstated. The problem was complicated by air conditioning requirements. In the case of existing buildings, the effort to vent these was quite considerable, but it paid large dividends. The aim was to provide 30 per cent venting space on all walls, partitions, and ceilings. Certain buildings were also suitably strengthened, and additional anchorages

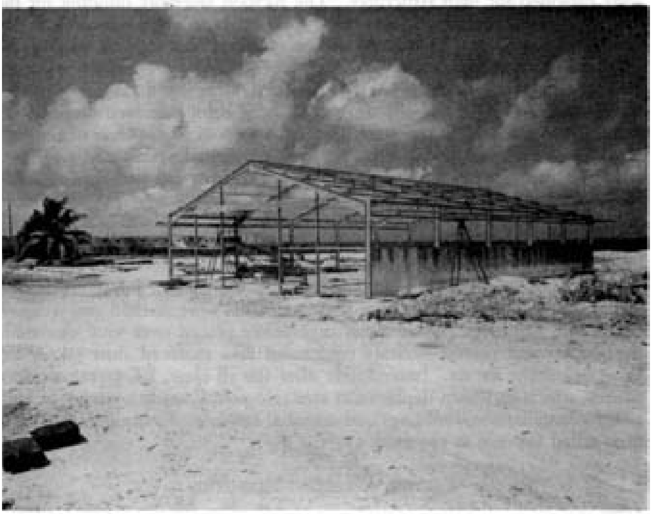


Photo 6. A Conder shed under erection.

***Photo 7.** The Junior Ranks Club under construction in the foreground. Completed sleeping huts can be seen in rear.

Engineer Support to the Christmas Island Nuclear Tests of 1958 - 6 & 7

were provided for high structures. The weapon assembly building for the low yield weapons, which were fired from balloons, was necessarily very close to ground zero. Thus there was no question of being able to avoid its complete destruction. However, the effort required on preparatory work for each subsequent low yield test was much reduced by arranging that the stanchion holding down bolts were capable of being removed immediately before an explosion. In the result the structure was blown clear of the concrete foundation and floor. With very little remedial action a new weapon assembly building was able to be erected on the original site, thus avoiding the considerable work of laying a new concrete base.

Other precautions included ensuring that large fuel and water storage tanks were at least three-quarters full to minimize differential pressure effects. Plant and vehicles were positioned end-on to ground zero. For high yield tests all serviceable aircraft were airborne at the time of burst. To avoid damage by secondary blast effect, loose materials were stacked and weighed down with sandbags. Wire mesh cages were placed over vital electronic equipment, and certain delicate equipment also required dust protection using polythene sheets. Immediately after the all clear, RE reconnaissance parties, which had been deployed at strategic points, made a survey of high priority installations, buildings and essential services. First aid parties were then called forward as required.

Factors Affecting Execution

Time

Grapple operations were similar to an operation in war in that time was the essence of the contract. The time factor was very tight and was only met by a vigorous and at times fairly ruthless approach. Maintenance of the objective was pressed to the almost complete exclusion of second thoughts. Results were achieved on the ground in about a quarter of the planning time which holds good for design and execution of work under average conditions. A further example of timing which might be of interest concerned the installation of lead-in lights to the main airfield. This requirement arose as a result of a hazardous but successful landing of an aircraft under conditions of extremely poor visibility caused by an intense tropical storm. There had been no previous warning of this requirement. Fortuitously, lights of suitable intensity were available on the island from stores used for temporary flood-lighting of working areas. Starting at a distance out of about 1,000 yards these lights were erected on a series of towers which reduced progressively in height down to ground level at the end of the runway. The installation was completed and in operation within three days of its first being demanded.

It is only fair to add that, in relation to work carried out on the island itself, the Chief Engineer was not encumbered with contract procedure. Furthermore, he exercised local financial as well as technical control, which was also an advantage in terms of time. Expenditure was, of course, subject to audit and to overall financial control by Ministry of Supply officials in England. Finally, because the Chief Engineer also held the appointments of Chief Military Planner and Commander Army Task Group, decisions could be taken quickly, but it is hoped never lightly. On the other hand the sanctions payable for failure or for not meeting operational dates would not have been light.

*Photo 8. Troops with their backs to ground zero and wearing flash protective clothing during the count down for a megaton firing.

Photo 9. A representative Army Task Group Guard being inspected by Major-General Sir Henry Sugden, KBE, CB, DSO, MICE, when he visited Christmas Island as Engineer-in-Chief in March 1958.

Engineer Support to the Christmas Island Nuclear Tests of 1958 - 8 & 9

Weather

Intensive wet weather slowed down building work, particularly high grade concreting. It restricted the quarry output by interfering with the segregation of the various sizes of crushed aggregate. Heavy rainfall also reduced the output of the starmix plant because of the excessive moisture which had to be extracted in the dryer. Local flooding required remedial and preventative measures. Extremely dry weather, which was equally liable to occur, resulted in more effort having to be diverted to securing adequate water supplies. Again, fires were more readily induced as a result of the test explosions.

Morale

Morale was clearly the most important single influence. Soldiers knew why they were carrying out a task and in what way it contributed to the success of each test. Emphasis was placed on man-management, and junior officers took a keen personal interest in their men's welfare on the island and in relation to their families at home. There were no families on the island and the length of tour did not exceed one year. The mail service, which clearly can have a big impact on morale, was maintained at a high level of efficiency. A daily news sheet had a wide circulation. The scale of rations was better than at any other station for British troops, and catering by the Royal Air Force was of a high standard. Health was good. The total all-in sick rate, including both hospital and casual sick cases, averaged 0.9 per cent for the Army Task Group. Although there were no regular drill parades, standards of turnout, bearing and drill were always of a high order on the few occasions when military ceremonies were staged, such as, Queen's Birthday Parade and Guards of Honour (Photo 9).

Every effort was made to ensure that all ranks had a minimum of one week's leave from the island during their tour. This was taken at Hawaii, Fiji, or the adjacent islands. Except during brief stand-downs, personnel had little more than one day off work per week. A large variety of recreational pursuits were taken full advantage of by all ranks. These included soccer, hockey, cricket, tennis, volley-ball, swimming, dinghy sailing, fishing and water ski-ing. Hobby activities were also provided for, and photography and bird-watching were popular. A Christmas Island broadcasting service was introduced and its nightly programme, run on entirely voluntary lines, had a wide and appreciative audience. The inter-change of a few NCOs and men for several days with personnel from the Royal Naval ships proved a popular innovation. These men took their place as working members afloat as did their Naval counterparts in Army units ashore.

Materials

With the one exception of stone, all materials had to be imported in bulk by sea, either from the United Kingdom or Australia. This called for a considerable degree of forward planning, based at times on the crystal ball. Even that infinitely adaptable commodity bamboo was not grown on the island. It would have been invaluable for temporary works. A number of bamboo plants from Fiji were planted during the year, but naturally any resultant value would be very long term. Indents for common user stores (timber, cement, bitumen) had to be finalized a minimum of six months ahead, and procurement of prefabricated stores averaged about nine months. Contract documents had to be prepared, tenders issued and orders placed on suppliers. Delivery dates had to be synchronized with shipping movements. Ship loading was pre-planned so that, as far as possible, stores came ashore at Christmas Island in the order these were required. The voyage out took several weeks according to the speed of the ship. Each ship required about three weeks of hard work to unload, and about a further two weeks was occupied in distributing cargo on the island. Temporary protection from weather had to be provided for stacked stores to avoid deterioration from climatic effects. A number of small stores and spares were imported by air, but clearly this line of supply had to be used sparingly with freight costs being approximately one pound sterling for each pound by weight.

Plant

Plant is becoming more and more a keystone of military engineering, and every sapper officer should be well versed in its efficient employment. Scaling of plant and vehicle spares is all important. This had to be kept under constant review in the light of experience gained on the island. Limitation of the different types of plant was essential. If a new type of plant had to be imported, it was vital that it underwent adequate performance tests in the United Kingdom before being dismantled for shipping.

The attrition rate on plant and vehicles was high for these reasons:—

(*a*) The tempo demanded shift work; thus plant and vehicles were worked at least sixteen hours a day for six days a week.

(*b*) Climatic conditions induced heavy corrosion, and dust caused abrasion of moving parts. Salt water was liable to seep into bearings and emulsify the lubricating oil.

(*c*) The majority of operators had to be trained on the job, and this added inescapably to wear and tear.

The only antidote was constant pressure on preventative maintenance. Much of the routine daily maintenance on plant and vehicles was carried out by specialist teams working during the night. Mobile fitter teams serviced plant at working sites, and carried out minor repairs. Breakdowns were recorded and analysed in order to trace the cause.

Conclusion

Perhaps the most outstanding lesson of these Grapple Operations was that the British troop of today is well capable of maintaining and enhancing the reputation of his predecessors. His capacity to undertake heavy and arduous work, very willingly and effectively, was well proven. Working in such close contact with the Royal Navy and Royal Air Force induced a very real and enduring mutual respect at all levels between the three Services. The associations with the scientists aroused a high regard for their work. The trend of inter-Service dependence is rightly on the increase, and the general training value of these joint operations is indisputable. An important by-product of the trials was the indoctrination of the troops taking part into the effects of nuclear weapons.

The flexibility and resilience of Royal Engineer units is impressive. Given the necessary backing in planning potential, a small element of Clerk of

Works, and a few specialist tradesmen as required, the good sapper field unit proved that it can tackle successfully complicated projects, which are extremely diverse in nature and call for a high degree of precision. A number of National Service officers and men were represented in the engineer force. In keeping with their creditable performance in other theatres, they stood up well to the rigorous conditions. The experience they gained on Christmas Island must have benefited them on their return to civilian life, particularly as young Officers and NCOs were given plenty of responsibility. It is not only a question of their having obtained professional and technical experience to a degree unique in their military service. Even more important, the calls on initiative and resourcefulness must have contributed much to their development in character.

A prerequisite to the start of planning should always be a critical examination of the requirement as defined by the user. This joint exercise carried out by planner and user together is the only real insurance against abortive planning or an unsatisfactory end product. Once the requirement is agreed in this way, excellent reasons for departing from it are liable to be advanced subsequently. Particularly when time is short, the price payable for change can be high and more often than not is prohibitive. The best is the enemy of the good, and, when time is at a premium, undue emphasis on the good may result in not even the adequate being attained. This does not imply any lowering of standards. Nothing is more wasteful in manpower nor disastrous to morale than acceptance of shoddy workmanship. It is largely a question of defining the scope correctly. The only criterion is a satisfied customer, but his satisfaction counts for little until after the project is physically completed.

The success of an engineering operation such as this stems to a considerable extent from the pattern of basic training given to officers and men. Thus the results achieved can be regarded as a tribute to the type of training given in the Royal Engineers. In the course of their training, RE officers carry out operations at the level of the sapper. For example, they act as working numbers in bridge building and in building construction. There is a direct parallel in the training of the embryo mechanical or electrical engineer in civil life, in the fairly wide experience they gain on the factory floor. The former will probably help to assemble a turbine and the latter may wire a stator. In contra distinction the young civil engineer sometimes receives a very restricted practical training during which undue emphasis is placed on levelling and quantities. Whilst ability to survey is a vital tool in his bag, it is by no means the only tool. Although in the final result the calibre of the civil engineer in this country is very high, nevertheless, it has been the author's experience that the young civil engineer starting for the first time on a working site appears to lean more heavily on his inspector or his foreman than the young sapper officer does on his Clerk of Works or his troop sergeant. For example, the embryo civil engineer might be given some practical training in concrete construction in view of the increasing demands for higher quality concrete. It is well known that quality does not stem alone from the design and trial of a mix. Equally important factors which can affect the final result are the control of mixing, methods of distribution, placing, vibration and curing.

Opportunities in peace-time soldiering to carry out engineering projects on the scale of Christmas Island are all too few. The recent introduction into the Army of the Civilian Works Organization has accentuated the problem of giving adequate experience in peace time to officers and NCOs on the type of civil engineering work the sappers are required to execute in war. The sapper officer must always be a soldier first, but the high traditions and the inherent attraction of the Corps are dependent upon his professional engineering standards being maintained at a level comparable with civilian life. The Corps is much indebted to the professional institutions, and to the Institution of Civil Engineers in particular, for the sympathetic and helpful attitude adopted towards maintenance of this vital aim. Individual members of the Institution have most kindly allowed Royal Engineer Officers (and occasionally senior NCOs) to play an active part in the execution of important works projects. Our colleagues in civilian life have much to teach us, and we on our part can perhaps contribute by bringing to bear a fresh point of view. It is of course only by the assumption of personal technical responsibility that the real lessons of a profession are learnt. We look forward to the continuance and extension of this close association with our civilian colleagues. In this paper emphasis has been placed on the importance of plant to the sapper officer. Opportunities to employ RE Officers and senior NCOs on civil engineering projects involving the use of plant on a large scale would be particularly appreciated.

In common with the carrying out of any engineering project, high morale on the working site must always be cultivated deliberately. Once attained, effort should be devoted continuously to maintaining it. By nature of his profession, and with emphasis more and more on speed of execution, the civil engineer is being called upon increasingly to assume a leadership role. It is a national characteristic that, given good leadership, the more arduous the task is, the greater is the response to challenging conditions. Maintenance of high morale perhaps poses less problems at times under military service than in civil life, but a common key to success in both spheres is undoubtedly a sound appreciation of the complicated mechanism of human relationships. Leadership training within the Service places much emphasis on a correct understanding of this fundamental factor. In the curriculum of the embryo civil engineer the introduction of some formal instruction in human relationships should prove of value. Leaders are of course not created in the classroom. On the other hand, comparatively little but compulsory training in the fundamentals of human relationships should be preferable to the existing pattern of learning by hard experience on the job. It can be argued that when the price payable for the latter is a degradation of morale of the working force, however temporarily, it is prohibitively high. Perhaps with the abolition of National Service combined with the increasing complications associated with human relationships, the need is further accentuated for some mandatory management training to be given to the young civil engineer.

Acknowledgement

The author acknowledges with thanks the assistance given by Lieut-Colonel D. L. G. Begbie, MC, RE and Major R. A. Hilton, RE, both of the RE Planning Team, HQ Task Force Grapple, in kindly making available various records maintained by them, which included a report by Captain S. D. Lewis, RE, on the Stamix 40 asphalt production plant, and a report by Captain J. R. Alford, RE, on the crushing of coral slab.

REFERENCES

1. "The Christmas Island Trials Base", by Colonel J. C. Woolett, CBE, MC. (*The Royal Engineers Journal*, December, 1957.)

2. "Regiment in Top Gear", by Lieut-Colonel Clutterbuck, OBE, RE. (*The Royal Engineers Journal*, December 1959.)

3. "Christmas Island Nuclear Trials 1958" by the Author. (*The Royal Engineers Journal*, March 1960.)

Regimental Channel Crossing

By LIEUT-COLONEL R. L. CLUTTERBUCK OBE, RE

AT 4.35 am on Saturday 16 July, twenty-four men of 38 Corps Engineer Regiment set out in twelve home-made canoes from Folkestone and landed 6½ hours later at Wissant, on the coast of France. This was the culmination of two months of hard training, preceded by a month of canoe construction. We learned a great deal from the crossing and its preparation, and I believe that together they comprised a training exercise for sappers that would be hard to beat. Canoeing is growing in popularity in the Corps, and I hope that some of what we learned will be of interest and use to others who are, I know, planning to make a channel crossing the climax of their own watermanship training. I will deal particularly with the problem of a team crossing *en masse*, and, though I will touch briefly on the design and construction of our canoes and other equipment, I will give special weight to the evaluation of wind, weather and tides in the choice of a course and of the moment to launch the expedition. The last is by far the most difficult decision in a crossing of this notoriously treacherous stretch of water.

THE AIM

We declared our aim before we cut the first length of timber. Our aim was to set out as a team of twenty-four men from England and to reach France complete. No-one must give up unless the weather forced the whole team to abandon the attempt together.

Although the Channel has been crossed many times by canoe, no team as large as ours has ever tried to cross it, nor has any, so far as I know, set out to cross it with that aim. Their aim has nearly always been to do a fast time, and that means that the slower members have one by one to be picked up by their escort vessel, leaving the best pair free to go for the record. This is fine, but, for a regimental training exercise, I would suggest that our aim is a better one.

We asked, and received, much good and willing advice from others who had experience of the Channel—notably Mr. A. R. Waterhouse who holds the individual record, from Captain John Lee and others of the Royal Marines, and from a number of boatmen and harbour-masters in Dover and Folkestone. But many of the problems of crossing *en masse* were new. First, such a crossing demanded the selection of a team in which no-one would let the party down, even if exhausted by sea-sickness—and sea-sickness hits the spirit harder than it hits the flesh. Secondly, it required training in keeping tight formation at sea, and in paddling at a speed which all could maintain while still keeping something in hand for cruel twists of wind and tide over the last few miles. (The Channel is famous for these, and lived up to its reputation with us. Whereas an aspiring record-breaker can cut his losses and give up if he is clearly out of the running, this would have defeated our aim when once we had set out.) Thirdly, and most important of all, are the problems of picking up a large team if weather conditions do deteriorate. The bigger the party the longer this takes; the longer it takes the rougher it gets; the rougher it gets the more chance there is of canoes being scattered or capsized. The difficult decision—which we nearly had to take one day in training off Deal when we found ourselves fighting a sudden Force 5 off shore squall—is when the moment has come to start picking up. This would be an even more difficult decision to have to take within reach of the French coast, where it is most likely of all to arise.

EQUIPMENT

Canoes. Our aim naturally governed our choice of canoe. Robustness and stability were more important than speed. We needed a canoe which could survive for at least an hour *after* conditions had reached a stage where we must start to pick up the team.

The choice lay between home built (rigid) and factory made (normally collapsible) canoes. The latter have the advantage of being smooth-skinned and, therefore, faster and, of course, much easier to transport. Against that, you can build five home-made rigid canoes for the price of one Tyne or Granta, and they are more robust and stable at sea. The canvas skin is easier to repair and it may be that the difference in speed (some 20 per cent we found, in our training at Ullswater, where we had both types) might well be reduced by treating the rough canvas skin with liquid fibre-glass.

We chose the PBK 18, which I strongly recommend. You can buy the design, in the form of drawings and templates, from the designer (Percy Blandford) for a reasonable royalty, and the materials are mahogany, parana pine, marine ply and marine canvas. All of this is legitimate trade training material—and there can be no question that building boats to stand a channel sea is excellent sapper training. We had our canoes out in a full gale on Ullswater, and we were caught in that bad squall during our training off Deal. During the actual crossing, we ran into a steep and heavy beam swell near the Varne Sands, and, in the closing stages, some nasty breaking seas in the shoal water off the French coast. At no time did I feel any anxiety over the stability of the canoe or its robustness. I would not have felt so happy in a collapsible boat which does, literally, bend like a willow against the seas.

Paddles. We made about half our paddles in workshops. I recommend, however, the 'do-it-yourself' kit for paddles—it only adds about a pound a pair to the cost and they are better balanced. It is desirable for paddles to be broken in the centre, and free (but not too free) to be twisted to the feather best suited to the individual.

Spray Covers. Spray covers are, of course, essential at sea. You go right through the head seas, and you can be completely engulfed by a breaking following sea. The cover must button tightly round the waist, but must be easily unbuttoned (using press-studs) by a man upside down under the water in a bit of a panic. And it must open widely enough to let his legs come out freely—a man with legs trapped in an upturned canoe will drown. Our spray covers were specially made for us out of nylon cloth by the RSD at Barlow, working at great speed and cheerfully accepting changes in design as we went along. Of our many willing helpers and advisers, none worked harder for us than the ladies of Barlow.

Buoyancy Bags. There is only one rule for buoyancy bags—have as much buoyancy as there is room for. We did not have enough. Shortage of money forced us to rule out buying proper shaped bags (obtainable from Tyne and others) and instead to rely on football bladders and the inner tubes of every trailer wheel in the Regiment. Although this was ample to support the canoe, waterlogged, and both its crew *in the water*, it did not keep the waterlogged canoe high enough out of the water, once one member of the crew had climbed back aboard, to enable him to bail as fast as a steep sea would break in and refill it. Our only option, therefore, after various trials up to the last day off Margate, was to make a rule that capsized canoes would be kept upturned (trapping a large air bubble in the bilge) and be assisted by two other canoes until picked up by the escort vessel. This was *not* good enough; it is only in rough water that capsizes are likely, and in a sudden squall, several of such a large party might have capsized at once. With the wind blowing the upright canoes east with the tide carrying capsized canoes west, this could have led to an ugly situation.

Bailers. For bailers we used children's quart-sized rubber buckets, which are ideal. The face of the girl in Timothy Whites in Dover made an interesting study when a sapper Lieut-Colonel in uniform walked in and bought up every sand-castle bucket in the shop!

Painters. Painters should be long and strong, because the escort vessel will inevitably be a large boat if it is to be able to pick up twelve canoes. After starting with something smaller, we ended up with 4 fathoms of 1½ in sisal. Care must be taken not to allow the coil to become tangled in the feet of No. 1 of the crew, in case of capsize.

Seats. For a long passage, it is worth having something soft to sit on. Some used service life-jackets or blankets. Others thought it worth a few shillings to buy Dunlopillo or Lilo air cushions. Six hours is a long time.

Life Jackets. We borrowed inflatable life-jackets from 9 Para Sqn. They are ideal, as they do not restrict movement at all until inflated, and they do not surround the body with a sweat-proof sheath. We did, however, do much of our training in normal Service life-jackets, and they are perfectly adequate if others cannot be got.

Clothing. It's no use trying to keep dry—or you will suffer far more by being unable to sweat. If a cold wind is expected, wear the lightest possible wind proof jacket, with woollen sweaters underneath. Even wet wool is warm provided that it is protected from the wind.

Navigation Equipment. Navigation aids are essential in every canoe. We issued each with a chart (out of date 6d each) and sketches of tidal streams in the Straits for every hour after H hour (These can only be filled in at the final briefing); also compasses prismatic. We secured the latter in cut-down cases sewn onto the spray covers. Due to the flexible base the error was liable to be 10 or 15° either way. This would probably have been good enough to get to the shore in a fog, but for accurate navigation it was virtually useless. Fortunately visibility was good, and I steered mainly on points on the French coast, aided by directions from the escort vessel. We never really solved this compass problem. Probably a fixing to one side, on the coaming, would be the answer.

The Escort Vessel

The escort vessel *must* be big enough to pick up all canoes and canoeists, and have the means to do so quickly in a rough sea. Anything less would be foolhardy. Even a Force 3 head wind will quickly kick up enough head seas to cut speeds by half, which will throw out all calculations of course and tide. Force 4 headwinds and sea will exhaust most crews within a few hours, while Force 5 will stop them almost dead. Tides wait for no man and can quickly carry a badly delayed team beyond hope of reaching land for 12 hours. This in itself is no disgrace—but to allow such a situation to arise without adequate rescue arrangements really would be a disgrace.

Our escort vessel was the MFV "Marchwood Mariner", kindly provided by 17 Port Regiment. Her skipper—Sgt Rixon—is a fine seaman, with great ingenuity and a wise eye for the weather. In our three days training together off Deal and Margate, he worked his willing crew from dawn till dusk in devising and rigging the best gear for picking up, and, on the day before the crossing, picked up all twenty-four men and twelve canoes in 30 minutes—a remarkable achievement. He had that rare ability to speak his mind without being rude, and to leave officers in no doubt when he thought they were talking nonsense. The skipper of the escort vessel is undoubtedly the most important individual in the whole operation, and we couldn't have been luckier with ours.

In relatively smooth water, Sgt Rixon's method of picking up was to lower a net, with spreaders, into which the canoe drove, and was hoisted bodily inboard with its crew.

In rough water, the crew would have first disembarked up scrambling nets abaft the canoe net, while the painter was reached by a boathook. The canoe would then have been pulled forward into the net. In really bad conditions, of course, with twenty-four men to pick up, we would just have got the men up and jettisoned any canoes that were delaying the business. In a heavy sea, with the vessel head to wind, the derrick may be pitching 10 ft up and down, and the gear would either capsize the canoe as it came in or brain the crew.

Another problem is that a large boat for a large party needs deep water, and, in many places on the French coast, the "Marchwood Mariner" could not get within 2 miles of the beach. It is over these 2 miles, of course, that the roughest seas may well be met—particularly if the wind is against the tide. This was the precise situation which arose where we chose to land, at Wissant, which had been recommended by people who had used shallow draught escort boats. If I did the crossing again I would choose Sangatte or Bas Escalles, where there are two or three fathoms to within ¼ mile of the beach.

Many of the above points are, of course, only applicable to a mass crossing escorted by a large vessel. A fisherman's motor boat escorting one or two canoes can take them right up to the beach, and probably the best compromise with a big team is to carry such a boat on board the mother vessel—instead of the dinghy with a small outboard motor that we had, which was hardly reliable enough for a 3-mile run-in over the shoals, and I doubt if it would have been much use for rescue operations in a heavy sea.

The Choice of a Course

The choice of a course is governed by certain known factors—notably distances and tides—and others that can only be forecast—wind, sea and actual speed through the water. Broadly, a canoe crossing should take five to six hours—one full tide or two half tides. Tides in the Straits are notoriously strong, and for this reason and because of other commitments we set a bracket 4 days either side of neaps. The maximum stream at springs is nearly 4 knots. A canoe in absolutely smooth water can keep up over 4½ knots (5 mph), or less as the sea rises. Canoes are particularly vulnerable to head winds and the head seas that they create. The sea from a Force 3 headwind will soon reduce speed through the water to 2 knots—and no forecaster can guarantee less than Force 3. The flood tide surprisingly, is stronger than the ebb. The shortest crossing is from St Margarets Bay to Cap Blanc Nez (or Wissant) and is 19 sea miles (21 land miles). For a crossing planned to take five or six hours, this means starting at half tide, and being set one way for the first half and the other for the second. This is the normal recommended course, and the one on which all records have been broken. (See Figure 1.)

Record crossings have usually been made starting 2 hours after High Water Dover, when (paradoxically) there are still two to three hours of east-going flood tide to run. The disadvantage of this is that the canoe reaches the French coast when the westgoing stream is near its peak and, if the wind is west or southwest, this can kick up a nasty sea on the shoal water which stretches two or three miles from the French coast. The record holder (Mr A. R. Waterhouse) told us that he had several times had to give up within a mile or two of the coast. The actual records, however, are always broken on those rare days, after a long quiet period, when the sea is flat calm, and these conditions do not then arise.

The St Margarets Bay course can also be done starting at half ebb instead of half flood. This has two advantages. First, if the wind is westerly, there will be less sea off the French coast. Secondly, if headwinds cause unexpected delay, the canoes will be set east towards Calais by the flood as opposed to west beyond Cap Gris Nez by the ebb. The latter is the biggest hazard of all since recovery is unlikely before the turn of the tide, and the weather may not be kind for as long as this. (See Figure 2.)

The third alternative is to go from Folkestone to Blanc Nez, which is 23 sea miles (or 25½ land miles), starting at slack water, and allowing for being set seven or eight miles east in the 6 hours of flood. This course has the great disadvantage that unexpected headwinds could leave the canoes very badly placed at the turn of the tide, in danger of being carried west of Cap Gris

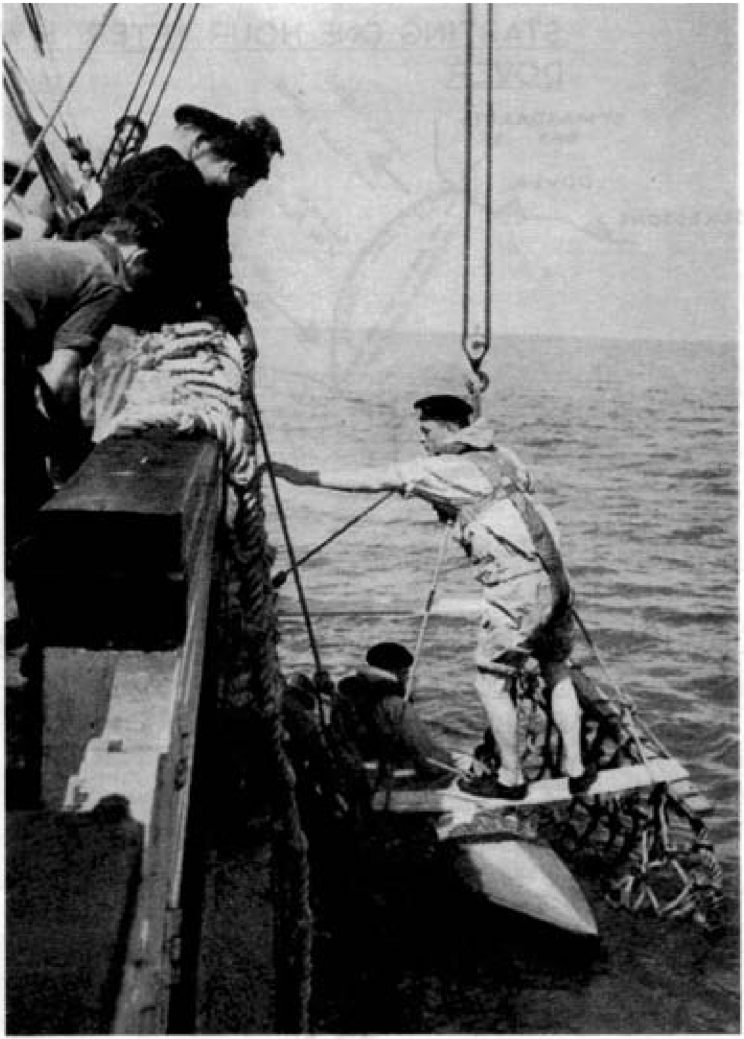


Photo 1. Practising the rescue drill. It was found better for both crew-members to stay in the canoe and be hoisted with it. Alternatively, in rough weather, for both members to get out before the canoe was put in the net.

Regimental Channel Crossing 1

FIGURE 1. ST MARGARETS BAY – CAP BLANC NEZ.
STARTING ONE HOUR AFTER H.W. DOVER.

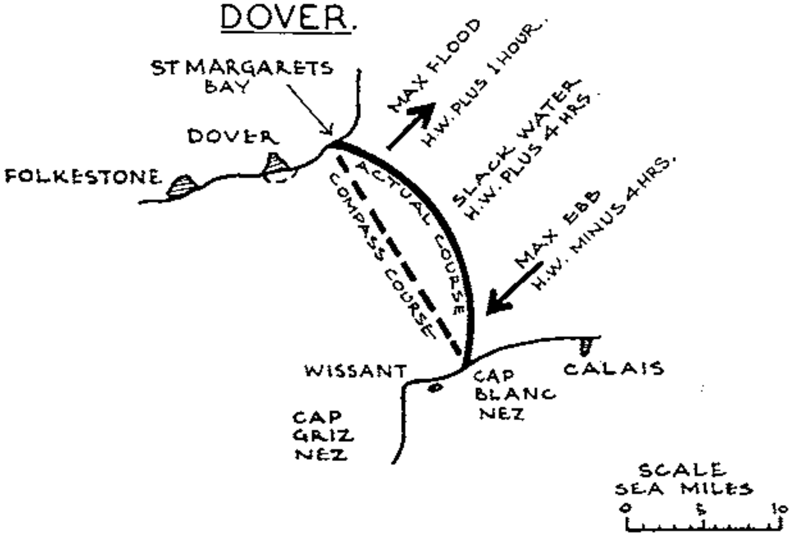


FIGURE 2. ST MARGARETS BAY – CAP BLANC NEZ.
STARTING 5 HOURS BEFORE H.W. DOVER.

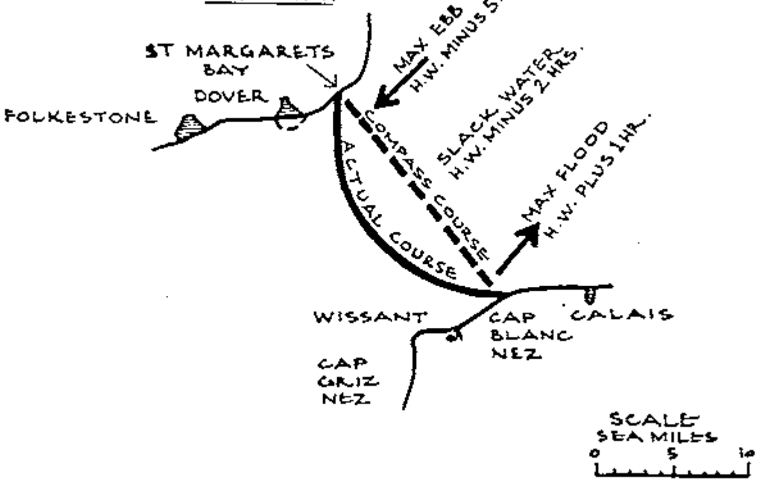


FIGURE 3. FOLKESTONE TO CAP BLANC NEZ. STARTING AT SLACK WATER (2 HRS BEFORE H.W. DOVER.)

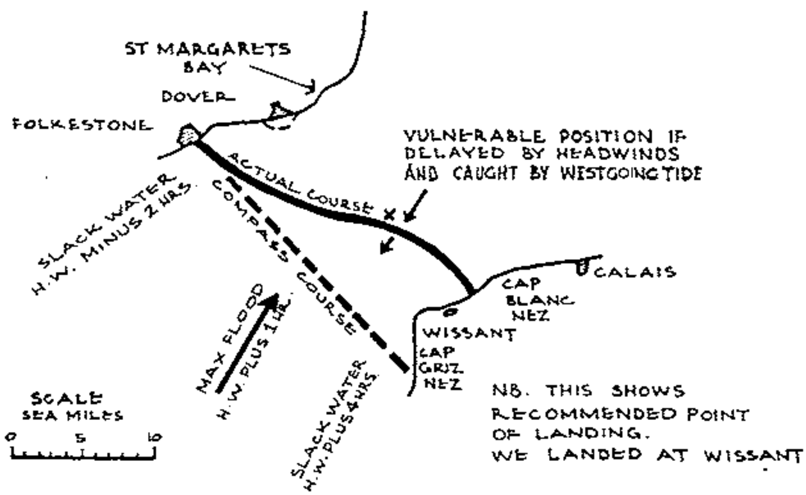
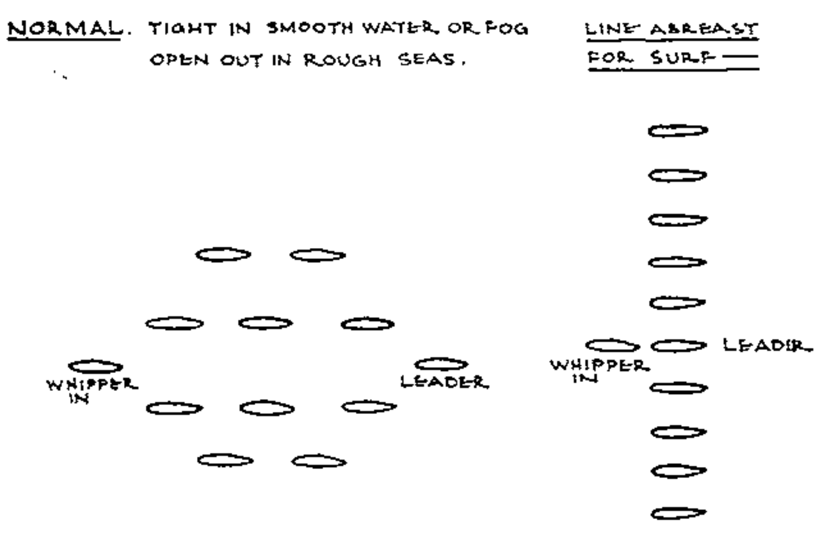


FIGURE 4. FORMATIONS USED FOR 12 CANOES.



Nez with the whole 6 hours of the ebb still to run. (See point X on Figure 3.)—This would leave a choice between being picked up (itself a hazard with a large team in rough water) or of staying another ten or twelve hours at sea. The Folkestone course is at least $4\frac{1}{2}$ miles longer, both in fact and through the water, because the flood tide has a northerly bias—which is why most Channel swims are done from Gris Nez to the South Foreland on the flood—so it means an hour's extra canoeing. In spite of this, however, in prevailing westerly conditions such as we had it is probably the best, as wind and tide are never opposed. That is why we chose it.

It is important to be realistic about the estimated time of the crossing, since the tidal streams setting across the course, even at neaps, may be well over half the speed of the canoe. Allowance must also be made for the fact that any prolonged headwind will lengthen this time by several hours.

The double canoe record, in a smooth-skinned racing canoe with the sea like glass is 3 hours 38 minutes over the short course (Figure 1). Based on our Ullswater trials, the PKB 18 (NOT treated with fibre glass) would take some $4\frac{1}{4}$ hours with same crew under the same conditions. We expected a heavy residual swell from a week of Force 5 to 7 westerly winds, and a Force 3 to 4 beam wind—far from ideal conditions, but not too slow. To keep something in hand for the backing and freshening winds forecast towards the end of our crossing, we planned two 15 minute rests, rafted up, at sea. Allowing an hour for the extra distance of the Folkestone course, $\frac{1}{2}$ hour for rests and $\frac{1}{4}$ hour for the fact that we would be in formation and not all record breakers, we calculated on $4\frac{1}{4}+1+\frac{1}{2}+\frac{1}{4}=6$ hours. In the event, our rests must have compensated for themselves somewhat by making us fresher, because after 5 hours we had only 3 miles to go, and were heading for a $5\frac{3}{4}$ hour passage. Then the wind backed round to our starboard bow, Force 4, and the last 3 miles took $1\frac{1}{2}$ hours. But for navigation purposes, the 6 hour estimate had proved near enough.

To sum up. Given a smooth sea after several days of fine weather, go from St. Margarets Bay. If there is little or no wind, or if what there is, is from the east, start one or two hours *after* H W Dover. If the wind is west or south-west, start four or five hours *before* H W Dover, bearing in mind that your roughest water will then be in the first few miles. If, however, there has been a prolonged period of Force 4 to 6 westerly winds or worse, wait for a lull and set out from Folkestone, starting at 2 hours *before* H W Dover (which is the start of the eastgoing stream). For this to be possible, the wind must be light for the previous 6 hours (against the westgoing ebb). This will allow the sea to subside into a swell. But bear in mind that if the wind revives during the crossing, caps will form on the swell and it will become a dangerous sea within half an hour; and a headwind may hold you back to a vulnerable position off Gris Nez at the turn of the tide. So your picking up drill must be well rehearsed.

Training

Preliminary Training and Team Selection. We selected the date for our crossing (the mid July neap tide period) in April.

Throughout May and June, we sent parties of six at a time to a training camp in the grounds of the Outward Bound School at Ullswater —whose kindness and co-operation was immense. This course combined canoeing and hill-walking, and ended with a 15 mile paddle against the clock. Three hours was broken once on this course (5 mph), and we later covered these 15 miles in formation, as part of our 25 mile paddle, in 3 hours 12 minutes.

From 50 volunteers who attended these courses, 26 (i.e. the team plus two reserves) were selected for a final week's training on Ullswater for the Channel crossing. Perhaps it was a blessing in the long run that we had filthy weather —wind and rain all the time. Such conditions bring out the best in people, and provided a better preparation for the open sea than fair weather would have done. Our final week's training included two long formation paddles of 30 miles and 25 miles. The latter took 5½ hours (including a 20 minute halt) and the formation at the end was as good as at the start, thanks to excellent "whipping in" by our trainer and team Sergeant—Black—in the last canoe. Our formation is shown in Figure 4.

We then moved to Dover, allowing a minimum of 2 days offshore training before our first possible date (14 July) and then up to 7 more days depending on how long we had to wait for the weather. In the event we had 4 days in all. Throughout this time, fresh to strong westerly winds blew without abatement, and canoeing off Dover was out of the question. We spent the first day in Dover harbour, which was far too restricted, and ruled out any manoevring with the escort vessel. The second day we spent off Deal in a fresh southwesterly wind, and did an invaluable 3 hour paddle under hard conditions, which gave us all great confidence in the way our canoes handled in a sea. The third day we planned to practice the pick-up drill in more sheltered conditions off Margate, but the escort vessel was in trouble and never came, so we did another long paddle this time testing particularly the canoes' ability to withstand a steep beam sea, which was much better than we had expected. We did not perfect our pick-up drill until the fourth day. This was a factor in our missing what might have been a gambler's chance of a crossing on that day; in the event this proved a blessing, though we might have cursed ourselves till doomsday if we hadn't had another chance.

Generally, we trained in the mornings (reveille 0600 hours) leaving the afternoons free for maintenance and administrative preparation while I concentrated on weather forecasts and yarning with boatmen on the harbour walls to decide whether or not tomorrow was to be the day.

The Crossing

The First Chance. At 1400 hours on the 14th, Captain John Hill—an ex-member of our regiment now serving with our hosts The Junior Leaders Regiment at Dover, and one of our most active and adventurous ocean racing skippers—bearded me with enthusiasm with a Manchester Guardian weather chart. He assured me that the BBC—who at 1340 hours had forecast west or southwest winds Force 4 to 5 for the next 24 hours—were wrong, and that at dawn next morning the wind would go northwest and fall light. This would, in his opinion, offer us a fleeting chance—probably the only one that would occur in the cascade of depressions roaring over England and still queued up malevolently all the way back across the Atlantic.

I rang Gatwick airport Met forecaster. To my delight, he agreed with John and not with the BBC, but warned me that by mid morning the wind would back to SW, Force 4 or 5 and increasing, so we'd have to start early and be really nippy.

I at once put preliminary movements in train for a start from Folkestone at 0430 next morning, subject to confirmation at 1800. Meanwhile I consulted other local figures—all of whom were disappointingly pessimistic. I was still unable to contact my most trusted adviser, a Dover boatman whom I will call Jim, as he was out somewhere in one of his boats. It was still blowing Force 5 to 6, and looked terrible. The 6 p.m. BBC forecast reiterated W to SW Force 4 to 5 for the next 24 hours which, if true, would rule a crossing right out. After listening to that I ran Jim to earth and he looked from his windows at the clouds over the French coast. "No" he said "I wouldn't touch it. There'll still be a very heavy swell. The seas are there, ready made, and it'll only need half an hour of wind to put white caps on 'em. And I don't like those clouds. If I were you, I'd wait a day or two."

On the BBC forecast alone, starting was out of the question. There was no doubt, however, that if the wind did drop that night, the swell, however heavy, would be safe enough at the start; but if, as Jim and Gatwick both forecast, the wind got up before we reached the French coast, we'd have to pick up—in a ready-made heavy sea. And, due to the escort vessel's breakdown, we had still never practised a 100 per cent pick-up, even in sheltered water. Sadly, at 7 p.m., I stood the team down and told them why.

That evening I spent dining with Dick Waterhouse, the holder of the cross-channel record and British long-distance championship. As always throughout our preparations, he was full of interest, help and advice. He is the kind of man who will one day coach someone to knock his own name off the record book, and will personally urge him over the last quarter mile to make sure he does. It was still blowing Force 4 or 5 at midnight, and I went to bed convinced that we were right not to be going.

But John Hill proved right. The wind dropped dead in the early hours. Next morning, there was John's light north westerly breeze. There was still a heavy swell but nothing vicious. Hourly wireless reports from our officer on the French coast reported good conditions until 10 a.m., when he reported that white horses were beginning to appear. By then we would have been within striking range. I have little doubt that if I had taken John Hill's advice we would have got across—uncomfortably but intact.

Were we right not to snap up the chance and risk it? John Hill—"Go! Now!" Gatwick—"You might make it if you start in the early hours." Jim—"wouldn't touch it. The sea's ready made." BBC—"Force 4 to 5 broad on the beam". The ultimate factor was that we hadn't yetperfected ou pick-up drill.

Fate does not often give a second chance to those who spurn her first offer, but this time she was kind. She offered one more chance—but only one—in the seven days remaining before the date when the tides would be too strong and the "Marchwood Mariner" would have to leave us. If they hadn't offered that second chance I'd never have forgiven myself for not taking John Hill's advice.

D Minus One. The escort vessel had waited for us overnight off Margate, and we were up at 0600 to rush through the safety drills with no further delay. The crew, as I have said, picked up the whole team in 30 min. We also did a trial capsize, with the other canoes bringing the upturned boat into the net and the crew getting up the scrambling nets. That completed our training.

All the morning the wind remained light, and at lunch time I had to face John Hill. Hands on temples, like a character in a Greek tragedy—"You ought to have gone! You'd have been there by now." He was right. We would.

By 1400 the wind was up to Force 5 again, and it seemed that our chance had gone. At 1630—with tide conditions as at 0430—I walked to the end of Folkestone outer harbour wall. The sea was wild and steep, though not so big as the day before. Another drop in the wind at nightfall was forecast—which I checked this time with the central Met office at Dunstable. "Force 3—you can't hope for much less than that. But it'll be west or northwest till mid or late morning. Then it'll back southwest and freshen. You might make it if you start early." This time I was determined not to miss the chance.

I listened to the 1800 BBC forecast with the skipper of the escort vessel, Sgt Rixon. The forecast agreed with Dunstable, so although it was still blowing Force 4 to 5 with nasty seas outside Dover harbour, we decided to launch in Folkestone harbour at 0430, with the "Marchwood Mariner" out to sea to confirm by radio that the seas had subsided enough to start. I told the team that if it was settled enough to start, the sea would subside as the flood tide gained strength, and we would get there.

A final visit at 1930 hrs to Jim and his telescope, gazing across from his window to the White cliffs of Cap Blanc Nez. The wind was beginning to drop. "You've got a chance if it goes on dropping. But look at that trawler out there. There's still a swell all right. The wind'll back around later on tomorrow. You may have to pick up. Make sure that you keep in really tight formation. Good luck anyway, *on your first attempt*."

It was he who had escorted Dick Waterhouse on his record run—after twelve false starts!

By 2200 the wind had dropped dead. 2300, midnight—same. Midnight forecast—Force 3 decreasing to 2, but backing to SW later. With no wind the swell really should be subsiding. The other end—1000 to 1100—would now be the problem. We advanced the programme by half an hour—to leave the harbour mouth at the earliest possible light in which the escort vessel could see the canoes. This meant reveille at 0200 hrs.

D Day. For the final month of preparation we had had a team manager—Captain Neville White. He had been down to Dover, over to Calais and Wissant, had bought equipment, designed and arranged manufacture of spray covers, changed francs, fixed bedding and food for our night in France and had dealt with the Press and the BBC, who, since the start of our training, had shown a most surprising interest seeing how often the channel has been crossed before. Neville never sat down during that night at all until he was aboard the escort vessel. His final duties included marking up twelve tidal charts and fixing meals, snacks for rafting up, emergency rations, and seasick pills. There's no need to say what else he dealt with, because he dealt with everything in the article—except the Met study, and the decision as to where and when and whether to start, which obviously had to be mine. I can only say that, if the leader of the expedition is in a canoe, such a team manager is vital, and it is no exaggeration to say that the launching of the twelve canoes, exactly on time, with their crews fed and fully kitted out, at the chosen point, with the lights of the escort vessel winking off the harbour mouth, canoe net on the derrick, scrambling nets ready, in wireless touch, loud and clear, with both shores, and with food, changing rooms etc. ready in France, was the product of something like half the working hours of a first-class officer for a month. Nothing less would have sufficed.

The wind was still light from the NW as we came into the swell in the twilight outside. It was heavy enough on occasions for a crew to be unable to see either any other canoe or even the top of the escort vessel's mast from inside the troughs. It was a beam swell, but there was no bite in it. We made 9 sea miles in the first 2 hrs, and rafted up near the Varne Sands buoy for a snack.

After that, the swell became steeper and more confused in the wake of the Varne Sands, and one or two men were seasick in spite of the pills, but to their credit they did not flag and the team kept perfect formation, still averaging 4½ knots. Then Sgt Black, the whipper in, came forward and reported that sea sickness was causing some crews to labour, so we advanced the second raft up by 20 min. This paid off well—Black had trained every man from the start, and, whipping up and down the formation, his judgement of them was sure and sound. He was a magnificent trainer and leader, and one could write a book about his methods of keeping up morale. If you recall Sgt Nelson in "They Died with their Boots Clean" you'll have a fair idea of how he set about it.

With only 7 miles to go, we set off like giants refreshed, and by 0935—H plus 5 hours—we were only 3 miles from France. From here, the water was too shallow for the "Marchwood Mariner", which needed 14 feet, so I had asked her to alter her course and press on through a break in the shoal some 2 miles east (Bas Escalles) where she could get within ¼ mile of the beach to launch the dinghy which could then come across and see us in over the surf.

Soon after she had left us the wind got up—with devilish speed, and almost in our faces. There was a buoy ahead of us, two miles off shore, and it took us half an hour to reach it. Steep, white-capped little seas were knocking our speed right back to 2 knots. The ebb had set in, and I began to wonder whether I had been wise to wave away the escort vessel. A capsize now could take the victims and their two assisting canoes down past Gris Nez in an hour or two, and the "Marchwood Mariner" was already 2 miles away. Even if they spotted it (as Sgt Rixon assuredly would) the water would be too shallow for anything but the dinghy with its Seagull motor. Again fate was forgiving, and no-one capsized, but after an hour we were still a full mile from shore, and we were getting tired. The wind was increasing every minute and if it went on increasing we might still fail, as so many would-be channel crossers have failed, almost within grasp of the French Coast.

There then occurred one of those little miracles which to us, tired and anxious, seemed not a little moving. Wissant Beach—a fine stretch of sand sloping half a mile out from the cliffs—had been up till then deserted except for about half a dozen bathers, dots on the edge of the sand. But when we were a mile off shore, tiny black figures—too small for us to be able to distinguish their legs from their bodies—began to debouch from the village and from the camp sites on the cliffs around it. First in twos and threes, then in scores, and finally in hundreds, all streaming down the beach to meet—us! It was hardly believable.

That last half-hour seemed to go by in no time at all. The strengthening westgoing tide enabled us to head further off the wind, and as we came under the lee of the land the wind and sea began to ease. A French motor boat came up on our port side and a sailing boat, close hauled with sails ashake escorted us to the starboard. A hundred yards from the shore the breakers were clearly visible ahead, so we opened out into line abreast in order to ride in on the surf towards the brightly clad French crowd with ankles awash on the shore.

Photo 2. The vanguard of the French crowd wades out to meet us.

Photo 3. Touching down in France.

Regimental Channel Crossing 2 & 3

The team, on its mettle, took up perfect dressing and we felt the hoist of the first wave under us. We were carried forward on the crest, at rising speed. One canoe broached too and was presented upside down in a heap at the feet of the crowd. If anything was needed to make their day it was that, and an enormous cheer went up. The rest of us were borne forward at irresistible speed into the heart of a wildly cheering, highly coloured, emotional body of young French people on holiday, as gay and exhilarating as only the French can be.

It was our wireless champ which had first attracted their attention, and those with a smattering of English had translated what was coming over from the escort vessel. Eyes had been turned to seawards and had picked up the armada with its 48 paddle blades glinting in the sun. French Television cameras were there, with a large Press contingent, and the Maire of Wissant was waiting to greet us. From the depths of a polythene bag I extracted a letter from the Mayor of Ripon. We had hardly lined up our canoes on the beach before our LO with the champ thrust into my hand a message. Our set in Dover, on the report of our arrival, had transmitted a message of congratulations from the Chief Royal Engineer—the work of Major-General Sir Douglas Campbell who was that day inspecting the Junior Leaders Regiment where our set was located. This message gave us a tremendous fillip in our moment of success. It also made a vast impression on the French, and was eagerly reported by their Press.

After an hour of joyful and bilingual frolics on the sand, we delved into our canoes for more polythene bags with dry clothes, and were led to the changing rooms. After which the Maire stood the entire team champagne in the village, still surrounded by the inexhaustible French pressmen who gave us a truly royal splash next morning.

French lunch, French beach, French girls, French supper, French dance, French bus, and to bed on the decks of the "Marchwood Mariner" in Calais.

By next morning it was blowing a full Force 5 or 6, and cargo ships were burying their noses in heavy seas as we punched our way back, canoes lashed on deck, rolling and corkscrewing hideously, to Dover. More than half of us writhed in agony rendering our sacrifice to leeward, and thanking the Lord that we were not in canoes. One man was flung against a bulwark and was unconscious for 45 min. Our little lull was over. The 1960 summer was back to form.

Mountains and Molehills

It is reasonable to ask "Was all this palaver necessary? Is there really so much in paddling 25 miles in canoes to a point on a coast which you can see quite clearly on a good day?" The answer is that if you want to be sure of crossing within a short period (say, a week) of your own choosing—and Regimental programmes do not allow unlimited choice—then I would say the palaver is necessary. If, however, you are able to wait for a perfect day, it is not. It's as easy as paddling three lengths of Ullswater.

On a perfect day, after several preceding windless days, the Straits of Dover can be like glass, and you can pick out the houses of Wissant with the naked eye. On such a day you could walk into a shop, buy a canoe without a spray cover, launch it without an escort vessel, and step out 5 hours later on the beach at Wissant.

But such spells of weather are not to be had for the asking.

Not long before our crossing, a team about half the size of ours left Dover for France. Two of them were going for the record, and forged ahead with their escort vessel. The others plugged on, heading generally south. After 8 hours, they could see neither England nor France nor their escort vessel, and they had no idea where they were. They put up a distress signal to a passing aircraft, which dropped them a marked map. They were well to the west of Gris Nez, and the ebb tide was running. After 14 hrs, they reached the French coast, with two of their number unconscious from exhaustion.

This was in the quietest conditions—no wind, no sea. Had the wind got up their fate can be imagined—certainly by the men of our team who saw the changed face of the sea a few hours before and after our crossing.

Our exercise was financed as Adventure Training. Adventure Training would be a misnomer if there were no real hazards. But the hazards should not be sought for their own sake. The aim must surely be to be so organized as to forestall the hazards as far as possible, but so trained that they can be mastered if they come. This is the right approach for entering any operation of War, and in that way I believe this exercise, the training, the preparation and the event, provided 3 officers, 3 sergeants and 18 junior NCOs and men of 38 Regiment with some of the best training that they had in 1960. As soldiers it proved them to be fit and self-reliant, and as sappers it gave them a trust in good craftsmanship and a feel for "The way of a ship in the sea." And their morale? Ask the people of Wissant!

Long Welded Rails

By MAJOR C. F. ROSE, RE

INTRODUCTION

MANY readers will have heard of the increasing use of long welded rails by railway systems throughout the world. Some will have seen these long lengths installed, either on British Railways or abroad, and enjoyed the smooth ride and absence of the familiar "clickety-click" of the rail joints. The more inquiring might also have reasoned that as the old rhythmic "clickety-click" was caused by the expansion gaps between short lengths of rail, the absence of these in long welded track poses the question of what happens to the temperature movement. Why, if there are no expansion gaps, does long welded track not buckle in hot weather? This article will attempt to answer these questions, as well as indicating the factors which have led to the development of long rails, describing their manufacture and installation, and discussing their possible military application.

In any future war, it may well be that military engineers will again have to take over the maintenance, operation, and possibly the reconstruction of civilian railways. These lines, both at home and abroad, will increasingly use long continuous rails and it is, therefore, necessary that military engineers should have some knowledge of the special problems and requirements of this form of track. The problem is not, furthermore, solely a Transportation one, as railway construction is now a commitment of the Corps as a whole. It is with this thought in mind, together with the hope that the subject might be of interest to the "non-railway" reader as a member of the rail-travelling public, that this article has been written.

The Problem

The history of railway track is one of continuous development since the early laying of "plates" on the mineral tramways of the north of England over a hundred years ago. However, in spite of great progress, railway track still remains a decidedly impermanent way. Of the many factors which lead to this impermanence, one of the most constant and serious has always been the difficulty of joining lengths of rail together The diversity of methods in use throughout the world, together with the long history of experimental joints shows the continuing desire for improvement in this field.

Virtually every joint produced so far has allowed some degree of discontinuity in the longitudinal section through the top of the rail. This causes an instantaneous change in the direction of motion of the wheel passing over the joint, and it is this which gives rise to all the troubles associated with joints. With conventional bolted fishplates even a small amount of wear allows "play" in the joint, and the trailing rail deflects under load, causing the wheel of a vehicle to strike the leading rail and to jump a short distance. This introduces a battering effect at the joint, which in turn leads to increased wear of the fishplates and a progressive action results. Reference to Fig 1 will show this action.

The difficulties which result from this weakness at the joint may be summarized as follows:—

(*a*) Increased wear at rail ends, necessitating renewal before the remainder of the rail has served its economic life.

(*b*) Working of sleepers at the joint, leading to disturbed ballast, deteriorated formation and consequent loss of level.

(*c*) Rail end failure. By far the greatest number of rail fractures occur near the joint, often being associated with the fishbolt holes.

(*d*) The necessity for frequent greasing of fishplates. This is a large item in all permanent way maintenance programmes.

(*e*) Poor riding characteristics for locomotives and rolling stock.

(*f*) Increased hammer-blow effect on bridges.

In an effort to solve the joint problem the use of longer and longer lengths of continuous rail has developed. By 1932 the German Railways were using 200 ft lengths of rail in low category lines, and soon after the end of the last war both the German and French railways started to install considerable mileages of track welded into continuous lengths of up to half a mile. Canadian and United States railways are also rapidly extending the use of long welded lengths over their systems. In this country progress has been less spectacular although now, following much theoretical and experimental work, long welded track is being increasingly used and there is no doubt that the future will see a great extension of such construction.

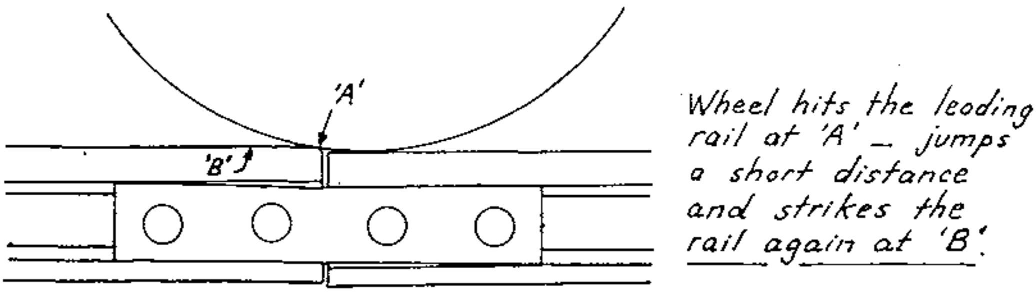


Fig. 1.

Conventional Rail Joints

Before dealing with long rails a brief description of conventional joints may assist.

Since the earliest days the normal method of joining rails has been to use bolted fishplates. These enable short, easily handled lengths of rail to be used, and provide a means of taking up temperature movement. All manner of designs have appeared, but the various attempts to improve the joint have concentrated on one of the following three approaches.

(*a*) Stiffening the joint to reduce the discontinuity.

(*b*) Providing increased sleeper support under the joint or close to it.

(*c*) Halving or scarfing the rails to cover the joint.

The usual method of stiffening the joint is to provide longer and stiffer fishplates. As many as eight bolts with 36 inch fishplates have been employed. The disadvantages of this solution are that wear will, in time, bring back the discontinuity and the longer fishplates require the sleepers to be placed farther back from the joint.

Attempts to increase the sleeper support at the joint are typified by the two-hole fishplate. In this case the sleepers can be brought very close together, but the greatly decreased stiffness of the joint leads to an intensification of the effects of discontinuity and the final result is little better than with the long fishplates.

Attempts to scarfe the rail ends have led to some interesting experiments. Perhaps the most notable was the Ellson Joint, developed by the Southern Railway before the last war. This joint gave great rigidity and good riding qualities, but was prone to fatigue failure and the cost was much greater than the conventional fishplated joint. A few of these joints are still in service.

The compromise solution between a stiff joint and close sleeper spacing is the 18 inch fishplated joint, now standard on British Railways. Fig 2 shows this joint with Bull Head track; Flat Bottom track is similar, with base-plates instead of chairs.

Comparisons between various types of joint have been made experimentally, and give a good indication of their relative stiffness. Fig 3 shows deflection tests carried out by London Transport using new fishplates with bolts tightened to a constant value. The results with worn fishplates would be correspondingly worse.

TEMPERATURE FORCES

When long continuous lengths of rail first came to be used there was a good deal of speculation as to how they would behave. It was obvious that with the normal expansion joints removed over a long distance there was bound to be a build up of stress in the rails due to the restraint of temperature movement. What was not known was the effect of these internal stresses on the stability of the track, and the actual movement to be expected at the free ends of the rail. As experiments progressed with longer and longer lengths of jointless rail, it became apparent that no drastic reduction in stability was occurring, and that the movement at the rail ends was less than expected.

To understand why this should be so it is first necessary to consider what forces occur in a length of track when free temperature movement is restricted. If contraction or expansion is entirely prevented the stress in the rails for a given temperature range will be

$(t_1 - t_2)$ Eq.

Where t_1 is the temperature at which the rails are fastened down (by driving keys or tightening bolts or spikes) so as to lock them to the sleepers.

t_2, is any subsequent temperature differing from t_1.

E is Youngs Modulus for the rail steel

q is the coefficient of expansion of the rail steel.

and the Total Load in the rail will be

$(t_1 - t_2)$ Eqa.

where a is the cross sectional area of the rail.

With full restraint these temperature forces may be quite large. For example, if a long welded rail is fastened down at freezing point, and the rail temperature subsequently rises to 80°F, the compressive stress in the rails will be about 4.3 tons per sq in and, taking 95 lb per yd bullhead rail, the total force "locked-up" in the track will be nearly 80 tons.

Now, for these forces to be realized, it is necessary for the rails to be completely restrained from moving. In the centre of a long rail this restraint is in fact provided by the action of two forces:—

(*a*) the resistance of the fastening between the rail and the sleeper to longitudinal movement by the rail.

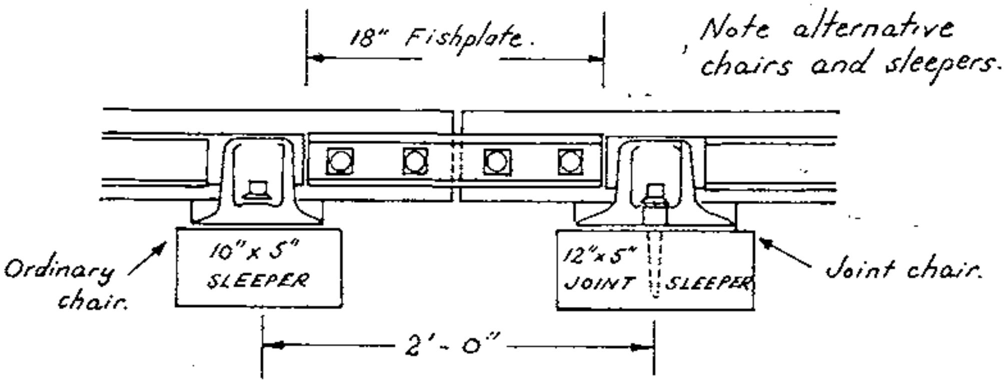
and

(*b*) the frictional resistance of the sleepers to longitudinal movement.

In other words, if the rail is rigidly clamped to the sleeper, and the sleeper is prevented from moving by the frictional effect of the ballast, then temperature movement is fully restrained.

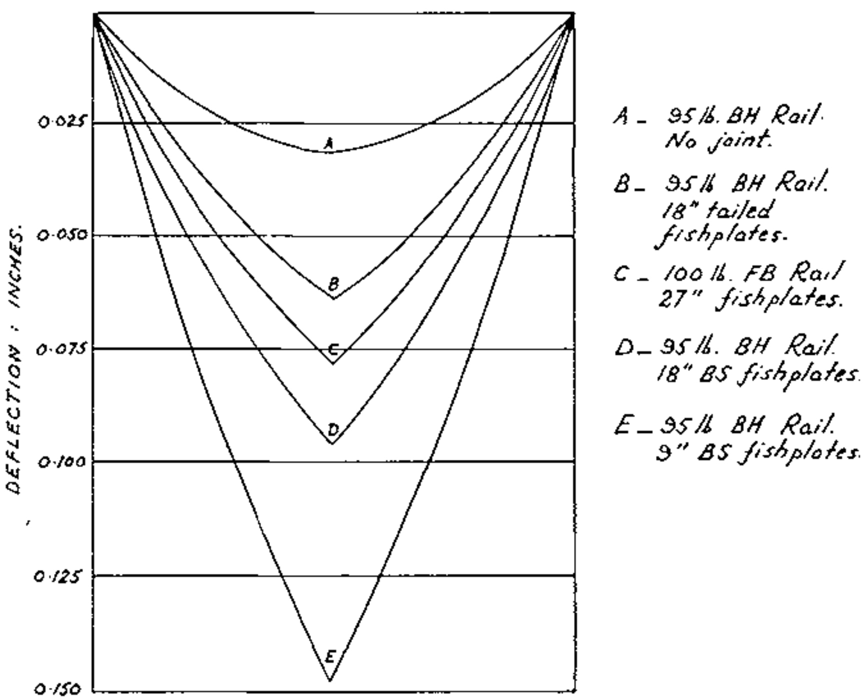
Many experiments have been made to determine the values of these two forms of restraint. The average resistance of a fastening to longitudinal movement of the rail varies between about 0.8 tons and 2.4 tons, and the resistance of a sleeper to longitudinal movement from about 0.2 to 0.6 tons. The fastening resistance, therefore, normally exceeds the sleeper resistance, although in practice it is not uncommon for rails to move longitudinally through their fastenings, showing that with less than perfect maintenance fastening resistance can become of lower value than that developed by the sleeper.

A common assumption for the investigation of temperature effects in a long rail is that the fastening resistance is sufficient to develop 75 per cent of



95 lb. BULLHEAD TRACK JOINT.

Fig. 2.



JOINT DEFLECTIONS UNDER STATIC TEST LOAD OF 8 TONS. RAILS SIMPLY SUPPORTED AT 3'-6" CRS.

Fig. 3.

the ballast resistance to sleeper movement throughout the length under consideration. Although this figure can be varied to suit conditions of very good or very poor maintenance, it has been found that 75 per cent gives close agreement with observations made on typical track.

With these two resistance values established for a given type of track it is a simple matter to calculate the length at each end of a long rail where actual movement may be expected, assuming that free movement is possible at the rail ends. For example, it was shown above that for 95 lb bull-head track a temperature range of 48°F causes a load of 80 tons in the (fully restrained) track. Taking a value of 0.6 tons for the frictional resistance of a sleeper, and assuming that the fastenings will be strong enough to develop 75 per cent of the total sleeper resistance, the number of sleepers required to "hold" a load of 80 tons will be

$$\frac{80}{0.75 \times 0.6} = 178 \text{ (approx)}$$

and taking normal sleeper spacing as 2 ft 7 in, the length of track at each end where movement can be expected is

$$2.58 \times 178 = 460 \text{ ft.}$$

The actual value of the movement at the free end of the long rail will be that due to the free expansion or contraction of half the "breathing" length over the temperature range. For our example the movement would be about 0.73 in.

It will be seen, therefore, that as soon as sufficient sleepers have been provided to develop a resistance greater than the temperature force in the track, the track can be considered fully restrained, and movement will not take place. This conclusion has been verified experimentally, and observed in practice. A long length of rail can be regarded as "fixed" except for a "breathing" length at each end, the extent of which will depend on the load in the track, and the values of fastening and sleeper resistance.

If free-ends are not provided at all (e.g. a long continuous rail of say, ten miles, built in at each end) then the whole length of track will carry the full temperature load, and there will be no movement due to expansion or contraction. The next section will describe the effects of this temperature load on the stability of the track.

Stability

Straight Track

Having determined the forces produced when rail movement due to temperature is restrained, the next step is to consider the resistance of the track to lateral or vertical deformation. Straight track will be considered first.

A section of railway track is a composite structure and obviously its behaviour will depend to a great extent on the ability of the various components to act as a whole. The determining factor in this is the strength of the fastenings between rail and sleeper. If these fastenings are weak and permit rotation of the rail in relation to the sleeper, lateral bending of the track will occur as shown in Fig 4.

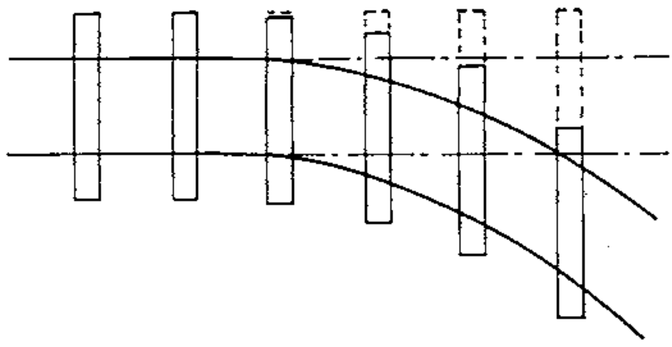
Resistance to a displacing force in this condition will be supplied by

(*a*) Frictional resistance of the ballast to transverse sleeper movement.

(*b*) The Moment of Inertia of the two rails acting independently.

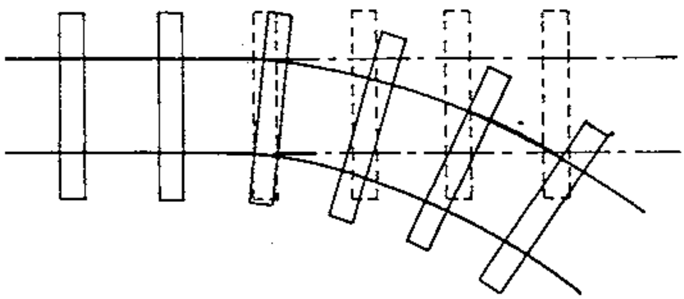
(*c*) The resistance to hinging of the rail fastenings.

If the fastenings are strong, bending will occur as shown in Fig 5.



BENDING OF TRACK WITH WEAK FASTENINGS

Fig. 4.



BENDING OF TRACK WITH STRONG FASTENINGS

Fig. 5.

In this case the track will act as a composite beam, the rails being considered as flanges, the sleepers as panel members, and the ballast as panel filling or "web". The resistance to bending in this case will obviously be much greater than the first.

Many experiments have been made to determine the resistance of various fastenings to rotation of the rail, and also the compressive strength of ballast. Results obtained show fairly high figures for ballast strength, but generally low figures for fastening resistance. It therefore follows that if only fastenings strong enough to resist rotational forces could be provided bending would take place as in Fig 5 and the considerable compressive strength of the ballast would be realized due to small movements of the sleepers out of parallel.

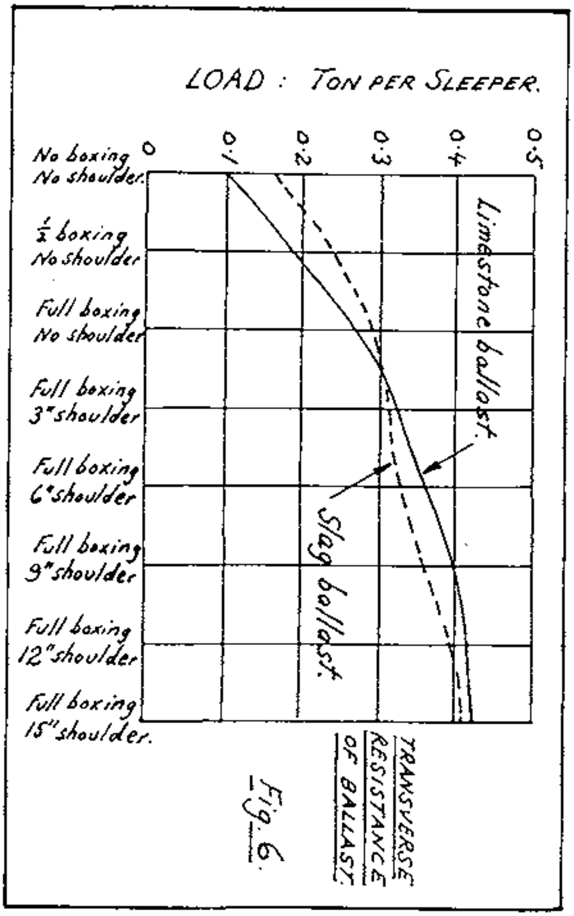


Fig. 6.

Values for the resistance of sleepers to movement at right angles to the track have been obtained experimentally. Fig 6 shows typical results for timber sleepers on limestone and slag ballast with various types of ballasting.

Other experiments have been designed to produce values for the equivalent moment of inertia of the track. The method normally used in these experiments is to apply horizontal loads at the ends of a number of sleepers in a length of track under various degrees of ballasting and to measure the lateral movements produced. These deflections, together with the measured radius of curvature, can then be used to determine the equivalent moment of inertia of the track acting as a beam.

Test results show that with small deflections bending usually takes place as in Fig 5 giving a high value for I. As deflection continues, the torsional resistance of the fastenings breaks down, bending as in Fig 4 develops, and the value of I is considerably reduced.

Values of I calculated from these experiments assume that all fastenings are in good condition. In practice this may not be the case and, therefore, values for I used to estimate the stability of track in service must allow for a certain percentage of the fastenings being loose or missing. The normal allowance for this is to assume that, in any given length of track, 50 per cent of the fastenings may be defective. It will be shown later that the critical lengths of track for the development of buckling are quite small and, therefore, this assumption does not provide such a large factor of safety as might at first be imagined.

The working value of I commonly adopted is, therefore, made up of the addition of

(*a*) The lateral moment of inertia of the two rails acting as separate beams. (This is a constant value irrespective of fastening rigidity.)

(*b*) Fifty per cent of the additional moment of inertia of the track acting as a composite beam, as determined by experiments.

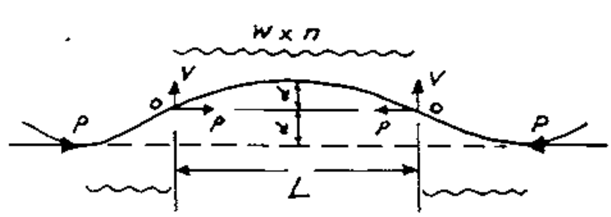
Values for I worked out on this basis for typical tracks are shown below.

TABLE 1

Type of track	Least equivalent moment of inertia with imperfect maintenance
95 lb BH	16 in^4
109 lb FB (elastic spikes)	26.6 in^4
109 lb FB (clip bolts)	40 in^4

Mention might be made at this point of the effect of using concrete sleepers instead of timber. Obviously the considerable extra weight will improve the sleeper resistance to lateral movement, and average values for I are, therefore, likely to be higher. The difficulty is to obtain a fastening for use with concrete sleepers which will produce resistance to rail creep and rotation comparable with timber sleeper fastenings, and also give acceptable insulation for track circuiting. In the past concrete sleeper fastenings have been deficient in these qualities. However, designs now appearing have largely overcome the difficulties, and British Railways are adopting concrete sleepers as standard for use with long welded track. Abroad, also, concrete sleepers are finding increasing favour, and many ingenious designs, both of sleeper and fastening, are appearing.

With the elastic characteristics of the track now determined, it is possible to investigate the behaviour of the track under load. Assume that an initially straight length of track has developed an approximately sinusoidal lateral deviation of magnitude + and − *d* from straight over a length *L*.



FORCES ARISING AT A SINUSOIDAL DEPARTURE FROM CORRECT ALIGNMENT

Fig. 7.

From Fig 7 it will be seen that at points "O" the load in the track has increased above P and a lateral force "V" has been added. The length O–O is under equilibrium due to the frictional force $w \times n$ supplied by the ballast resistance to lateral movement (w is the average ballast resistance per sleeper to movement at right angles to the track and n is the number of sleepers in the length being considered). Obviously as L becomes greater, the stabilizing force $w \times n$ will also increase, whilst V and P will remain the same. Therefore, for a given departure from straight, the risk of buckling is greater on short deviations than on long.

The actual length on which buckling is most likely to occur can be arrived at by considering the deviated length as a strut, hinged at both ends. In this case the buckling load is given by

$$P_e = \frac{pi^2 EI}{L^2} \text{ (Euler)}$$

From which

$$L = pi\sqrt{\frac{EI}{P_e}} \text{ where I is the equivalent moment of inertia}$$

For any longitudinal load P, therefore, instability will occur if a departure from straight develops of such magnitude that, on the Euler length L, $2V$ is greater than $w \times n$, where V is the lateral component of P and $w \times n$ is the total resistance of the ballast to lateral movement.

A buckle produced in this manner on the Euler length will be a single wave with no point of contraflexure. In practice a buckle is much more likely to consist of a series of alternating waves. However, this does not effect the determination of the critical conditions described above.

The evaluation of the amount of initial irregularity in line over the Euler buckling length which will cause buckling for a given load can be found by considering the length of track as a strut under lateral load. The exact mathematical analysis is somewhat complicated, and a simplified method will be given here which produces figures close to those found by more rigorous investigation.

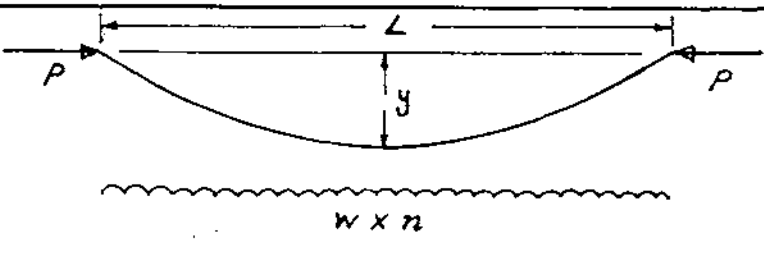


Fig. 8.

Fig 8 shows an initially straight length of track under a compressive load P in which a deviation of y has developed over a length L.

The maximum bending moment will occur at the centre of the deviation and will be $P \times y$. For the track to be in equilibrium this moment must be balanced by an opposite moment due to the resistance of the ballast to lateral load. This resistance is $w\,x\,n$. Therefore the balancing moment is

$$\frac{w.n.L}{8}$$

For equilibrium then,

$$P.y = \frac{w.n.L}{8}$$

It was shown above that for any load P the critical length L could be found. Therefore, for a given value of P and a ballast resistance of w the critical versine y is given as

$$y = \frac{w.n.L}{8.P}$$

The value of y given by this expression is the maximum deviation which will still be stable.

The more accurate analysis makes allowance for the fact that a buckle will in practice consist of alternating distortions.

From these equations a table of critical chords and versines can be drawn up for any type of track, using values for I and w determined by test. The following table serves as an example, and is for 95 lb *BH* rail on timber sleepers. I is taken as 16 in^4 and w as 0.41 tons per sleeper.

TABLE 2

P (tons)	Critical buckling length (feet)	Critical versine (inch)	
		Using accurate formula	Using simplified formula
20	26.9	8.9	8.64
60	15.6	1.0	0.965
83.5[1]	13.2	0.51	0.488
100	12.0	0.36	0.347
167[2]	9.3	0.13	0.121
200	8.5	0.09	0.086

[1]Equivalent to a 50-deg temperature rise.
[2]Equivalent to a 100-deg temperature rise.

The foregoing examination enables the stability of any type of track to be determined, providing values for I and w can be obtained experimentally. It will be seen that stability is directly dependent on maintenance, and if suitable standards can be laid down or estimated for maintenance, the factor of safety of any track can be found for given temperature ranges. As an example, on fairly good main line track with long-welded rails in this country, the maximum deviation from straight on a 12-ft chord is usually between 0.125 and 0.25 in. Taking the worst case, this represents an ability to withstand locked up forces due to a temperature range of about 72°F.

Curved Track

The stability under compressive loads of continuous curved track can be treated in exactly the same manner as with straight track. Curved track has an initial departure from straight and, therefore, this must be deducted from the critical versines given in Table 2 above. For example, if a long continuous length of curved track is limited to a temperature range of 50°F, then the critical versine for stability is 0.51 inch over a chord length of 13.2 ft. Assuming that the maximum deviation from perfect line due to poor maintenance is 0.25 inch this leaves a permissible curve versine of 0.26 inch. Over a chord of 13.2 ft this gives a radius of 968 ft or 14.6 chains. The inclusion of a factor of safety of 1.5 would bring the maximum permissible radius to about twenty-eight chains.

One case with curved track where particular care is needed is the reverse curve. The point of common tangent is prone to variations in alignment, and is critical from the point of view of buckling. In practice, therefore, a break in continuity is desirable at the point of common tangent in all cases where the curves are sharp or maintenance is likely to be poor.

Vertical Buckling

The possibilities of vertical buckling can be investigated in the same manner as lateral buckling. The value of I in this plane will be much greater, and the conclusion reached is that the deviations from straight necessary to cause buckling are very much greater than would normally occur even with an extremely poor standard of maintenance. With this type of buckling the weight of the track is obviously an important factor, and here the additional weight of concrete sleepers would be an advantage.

There are some cases where variations in level might occur, and these would require watching. Track might be humped over a bridge or level crossing, or long continuous lengths jacked up (e.g. for shovel packing) during maintenance. Sharp changes in level should, therefore, be avoided with continuous track and jacking up prohibited during warm weather.

Dynamic Effects

One important aspect of track stability which has not been mentioned so far is the effect of vehicle running on the temperature movement and general stability of the track. Opinion has been expressed that the heavy side-thrusts imparted to the track by locomotives and rolling stock, particularly on curves, should be allowed for in assessing the stability of a track. However, a study of actual buckles has shown that these seldom or never occur under traffic. This supports the view that the weight of the vehicle acting vertically down on the track increases the lateral stability to such an extent that any side-thrust is more than counterbalanced.

A second, and more serious, traffic effect is that of vibration. Experiments carried out by Western Region, British Railways, using a dynamic test rig which simulates the passage of a locomotive over a test length of track have shown that vibration can cause a reduction in the lateral rigidity of the track, as well as reducing the resistance of the fastenings to longitudinal and rotational forces. The exact evaluation of these effects presents many difficulties, and it cannot be said at present that firm conclusions have been reached. For the moment it appears that in determining the stability of a track these vibration effects must be kept in mind when deciding on a suitable factor of safety.

Conclusion

From all the foregoing it will be seen that for any given type of track there is a critical length and departure from true alignment which will produce a danger of buckling. The extent of this departure is directly related to the forces locked up in the track due to the restraint of temperature movement. Assuming a reasonable standard of maintenance and allowing a safety factor of 1.5 it appears that a temperature range of about 50°F is the maximum that can be permitted for really long lengths of continuous rail.

If this temperature range is likely to be exceeded, steps must be taken to release temperature stresses in the track. This is achieved by "de-stressing" which is a standard practice on most railways using long continuous rails. The normal method used is for a large proportion of the fastenings to be slackened off at a time of average temperature, and a locomotive passed slowly over the track. This enables the rails to move freely relative to the sleepers, thus releasing any locked up stress. Adjustment is made at the ends of the long rails (the method used will be described later) and the rails quickly fastened down again. In this country, most railways carry out this de-stressing operation twice a year; once during the spring and once in the autumn.

Note. The theoretical treatment followed in this section was first developed by London Transport as a result of a programme of experimental work carried out soon after the war. It has been adopted here as it provides a straightforward explanation of the behaviour of long-welded track. During the past seven years, British Railways have been carrying out a much more detailed series of experiments, designed to determine both the stability of welded track in the particular conditions obtaining in the UK, and the economic advantages to be gained by its use. Detailed results of these experiments have not, as yet, been published.

Fabrication of Long Continuous Rails

There are at present seven methods in use throughout the world for producing long continuous rails. All methods are based on the joining together of short rails of between 30 and 60 ft length. The methods are:—

(*a*) Electric arc welding.
(*b*) Oxy-acetylene welding.
(*c*) Gas pressure welding.
(*d*) Machined joints as used by London Transport ("welding with bolts").
(*e*) Adhesives.
(*f*) Thermit welding.
(*g*) Flash-butt welding.

Of these methods, (*f*) and (*g*) are by far the most common in Europe, and are generally accepted as giving the best results, although gas pressure welding, which is extensively used in America, also gives very satisfactory results.

Flash-butt welding

The flash-butt weld gives a joint more nearly approaching plain rail in strength and structure than any other process. It is best made in a depot using static equipment, although of late several railway authorities have developed mobile flash-butt welding equipments. These may be used to set up temporary welding depots in sidings or yards close to the work.

Flash-butt welding is normally used to produce continuous lengths of up to about 300 ft. Beyond this length handling and transport become somewhat difficult although, as long welded rails become more widely used, special facilities for dealing with really long lengths will develop. Already in France and on the North-Eastern Region of British Railways special depots have been built where rails of up to 900 ft can be produced and handled.

In flash-butt welding, the two rails to be welded together are clamped a short distance apart in a welding machine and carefully aligned. Alternating electric current is then passed through both rails and they are brought slowly together until current arcs across the gap between them. As soon as the arc is struck the rails are withdrawn. When the arc is broken, the rails are once more brought together, and this cycle is repeated until the arcing has raised the rail ends to welding temperature. The rails are then forced together under high pressure, and the weld is made.

A number of different automatic machines are manufactured, all working on the above principle. The A.1 Electric Welding Machine Company, Ltd. make a very robust and reliable machine (No. APHF/30R) which has been adopted as standard by British Railways. It is illustrated in Fig 9. The machine is of 300 KVA rating, and, operated by one man, it is capable of welding rails of up to 131 lb/yd section at the rate of a weld every 2 minutes. The butting force used is 30 tons.

One advantage which this machine has over many of its rivals is the clear opening at the joint, which enables the rails to be accurately aligned before welding, using a long straight edge. An automatic rail alignment unit may also be attached to the welding machine, and this ensures constant accuracy of alignment as rails are fed into the machine.

After welding, the weld upset or extruded metal must be removed. On most British machines this is done with a pneumatic chisel whilst the weld is still hot, the rail being automatically fed from the machine a distance of 10 ft into the trimming position. In France, and on the latest British machines, an extension to the welding machine carries a number of machine tools which cut the upset to approximate profile, thereby speeding up this operation. After the rail profile is trimmed, it is usual to grind the rail head to finished limits.

After trimming, the welded joint can be normalized by heat treatment, although this is a question on which opinion is still divided. In this country it has always been the practice to post-heat flash-butt welded joints up to about 850°C, the weld then being air-cooled. In Germany, post-heating has never been carried out, whilst in France it was invariably done until recently, when it was decided to omit all heat treatment. Fig 10 shows the variations of hardness which occur in flash-butt welding, and the effect of heat treatment.

It will be seen that without post-heating a very hard zone is produced, but this is limited to the immediate vicinity of the joint. Heat treatment reduces this hardness peak, but produces relatively soft zones extending for some distance each side of the joint. These soft zones wear fairly rapidly in service, and produce shallow dips in the rail table which can have a very adverse effect on vehicle riding over the joint. Opinion in Germany is that the answer is to concentrate on narrowing the extent of the zone effected by welding, thereby producing a very localized hard area. This is thought to be preferable to the more extensive soft zones. With close control of the welding process, German engineers are able to limit the heat effected zone to within about two inches from the joint.

Undoubtedly, heat treatment will help to produce a better grain structure in the weld metal, and this is often quoted as a reason for post-heating. However, failure of the actual weld does not appear to be any more common on railways which do not post-heat, so this contention is not necessarily valid.

One great advantage of flash-butt welding is that little depends on the skill of the individual welder. Provided that the machine is kept in correct adjustment it will continue to produce a constant quality of weld. Machines used on the Continent usually have recording devices attached to them which

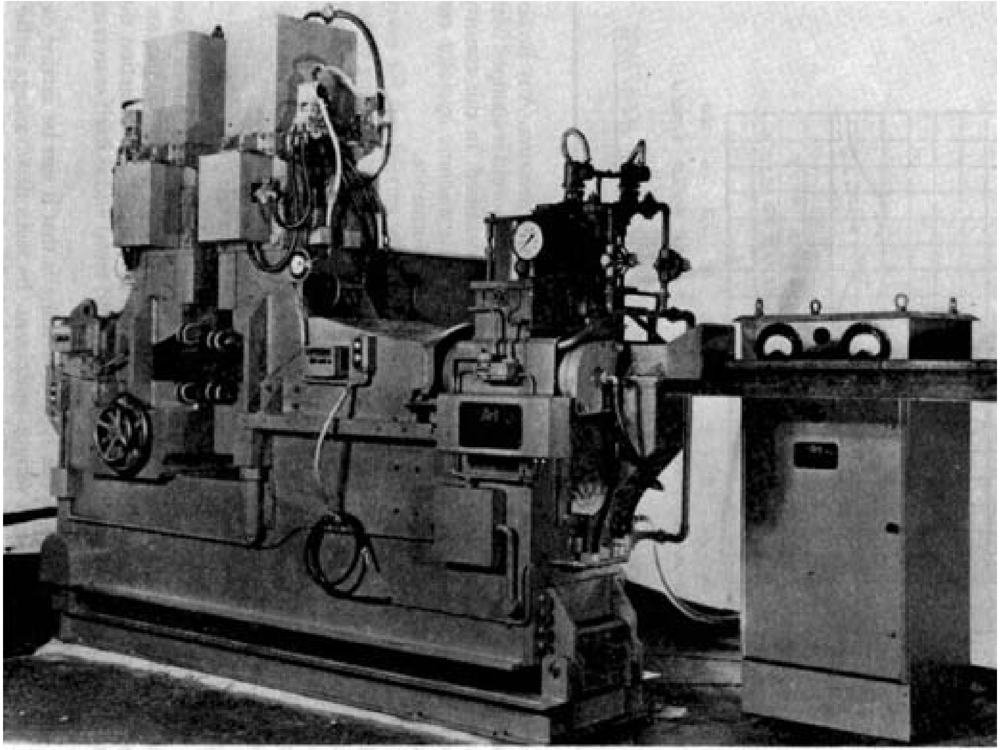
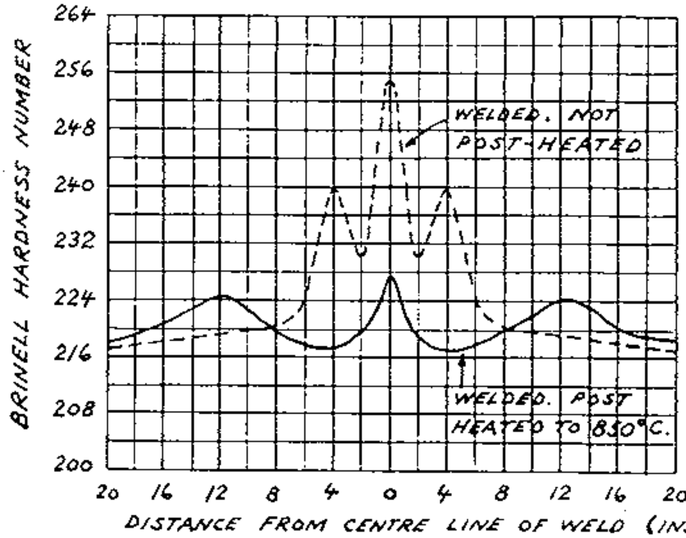


Fig 9. APHF/30R Automatic Rail Welding Machine



VARIATION OF HARDNESS WITH POST HEATING.
Fig. 10.

record welding temperature, platten travel and upset pressure. Any inconsistency in these can, therefore, be detected and, as each weld is stamped with a serial number, the corresponding joint can be identified. In this country recording instruments are not widely used, but the machine operator can usually detect any inconsistency in the machine performance.

Both here and abroad sample testing is normally carried out for every batch of rails welded. The tup test is used, the normal practice being to employ two blows of 7 ft tons. Periodically a much more severe test is employed, the drop of the 1 ton weight being progressively increased to a maximum of 20 ft. A flash-but welded joint will usually remain unbroken even with this maximum impact.

Thermit Welding

The "Thermit" process is based on the chemical reaction which takes place between an intimate mixture of small particles of aluminium and metallic oxides when heated to a suitable temperature. In the reaction the aluminium reduces the metallic oxides to liquid metal and is itself converted to aluminium oxide.

The great advantage of this type of welding is that it can be carried out *in situ*, using simple, light weight equipment. Its main disadvantage is that much depends on the skill and efficiency of the welder.

The procedure for making the weld is as follows:—

(*a*) The rail ends to be joined are cleaned with wire brush and/or oxy-acetylene torch.

(*b*) Correct alignment is checked and adjusted, using straight-edge and shims. The gap at the rail ends is adjusted to give half an inch.

(*c*) A brick-earth filled mould (shown in Fig 11) is clamped into position around the joint, and a benzole burner (shown in Fig 12) is inserted into the mould.

(*d*) The burner, which is fed from a portable vessel pressurized to 90 lb per sq in, heats the rail ends for approximately twenty minutes. The rail end temperature should then be between 700 and 750°C, and this is checked by using a temple stick (345°C) marking the rail head 1 inch from the outside of the mould case.

(*e*) Whilst the rail ends are being heated, a cylindrical retort is filled with the welding compound, which is a mixture of finely ground steel and aluminium.

(*f*) When welding temperature has been reached the retort, which has an alloy plug at the base, is positioned over a hole in the top of the mould, and the welding compound ignited. Ignition is started with the aid of a small quantity of magnesium, lit by matches. Careful control of the size of the particles of aluminium and steel, and the state of oxidation of the latter govern the speed of the reaction, so that steel in highly superheated molten state is produced. The temperature at the end of the reaction is in the region of 2,800°C.

(*g*) The superheated metal is then tapped into the mould, filling the gap between the rail ends. The degree of superheat is sufficient to cause the weld metal to dissolve and amalgamate with the pre-heated rail ends, and the whole mass becomes a single homogeneous structure on solidification. The fact that solidification takes place from the centre outwards assists in the escape of occluded gases, and a structure generally free from blowholes and slag inclusions results. Fig 13 shows the retort just before pouring.

h) After approximately three minutes for cooling the moulds are removed and the surplus weld metal is removed by a hot set and hammer. The weld is then "forged" using an iron and heavy hammer.

(*i*) The final operation is to grind the joint after re-checking with a straight-edge. This is done with a small portable petrol engine driving a carborundum wheel by flexdrive. Fig 14 shows this operation in progress.

A thermit welding gang working on rail joints *in situ* normally consists of four men. Of these only one is a trained welder, the remainder being labourers. Each gang has a small rail trolley fitted with a removable canvas cover so that work can continue in all weathers. A group of welding gangs is served by a central depot, where three or four men are employed on preparing the earth filled moulds. Other men take these prepared moulds out to the gangs, and bring back used ones for repacking.

With the welding system described above, the time taken to weld one joint is almost exactly thirty minutes. For planning purposes it can be assumed that each gang will complete two joints every 75 minutes throughout a working day.

These figures are based on the thermit weld at present carried out in this country. However, recently Messrs Murex Ltd of Rainham, Essex, who have developed thermit welding in this country, have announced their amalgamation with a German firm specializing in the same welding process. The main effect of the merger has been to make available a new technique which greatly speeds up the pre-heating of rail ends before welding. With this new method, the pre-heating time is reduced to six or seven minutes. This will, therefore, virtually halve the total time taken per weld.

Much the same division of opinion exists over the question of post-heating

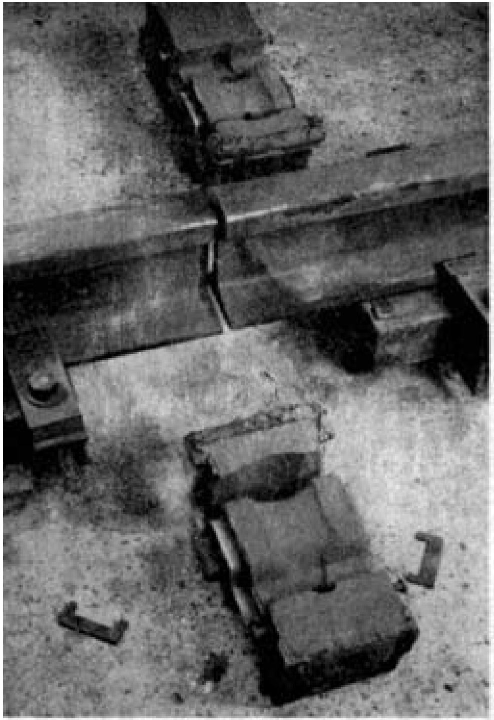


Fig 11. Rails set for welding 109 lb/yd rails

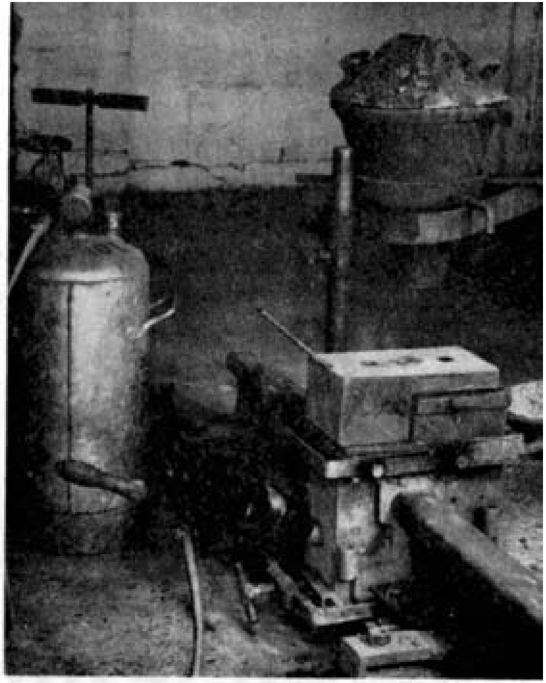


Fig 12. Preheating crucible charged and ready to swing into position for pair 109 lb/yd rails

Long Welded Rails 11, 12

Fig 13. Thermit reaction 109 lb/yd rails

Fig 14. Hand grinding running edge, 109 lb/yd rails.

Long Welded Rails 13, 14

as has been described in the case of flash-butt welding. Most authorities favour normalizing the joint after welding, and the rather greater susceptibility of thermit welded joints to failure in service supports this view on the grounds of improved grain structure.

Electric-arc and oxy-acetylene welding

Little need be said about these forms of welding as the techniques involved are well known. Until recently neither method was really suitable for joining rails as, with the exception of some light sections, the areas involved are too large to give reliable welds and a great deal of dependence is placed on the individual welder.

However, a new manual metallic arc method of welding rails *in situ* has been developed by the Phillips Electrical Co. and the Chief Civil Engineers Dept of London Midland region, British Railways, and has been found to give very satisfactory results.

In making the weld the rails are first positioned in line with a gap of not less than ½ in between the ends to be joined. A backing strip is secured under the foot of the rail projecting an inch or more on either side. The rail ends are then pre-heated to about 400°C and welding is commenced using Phillips EW electrodes, which are of the basic coated low hydrogen type. The electrode is held vertically in the gap between the two rails and metal deposited straight across the joint, the first layer being deposited on the backing strip and fused to the bottom edges. Welding proceeds with subsequent layers deposited in the same way until the whole of the foot up to the lower fillet radius has been welded. At this stage copper dam pieces are secured to the sides of the joint in the web, a small gap being left between the pieces of copper and the rail to allow slag to escape. The web is then welded and further pieces of copper are placed under the head on the upper fishing surfaces, and against the sides of the head as welding proceeds up the section until the top of the head has been completed. The dam pieces are then removed and the weld at the foot and head is ground or machined flush.

Gas Pressure Welding

In this type of weld the rail ends are brought together at a pressure of 2,700 lb per sq in and heated by a gas flame until a ⅞-in shortening is obtained. The joint is then normalized by heating to about 1,500°C and naturally air cooled. The rail head is finally ground down to correct profile. As well as producing a very satisfactory weld, the method has the advantage of simplicity. The equipment used is relatively inexpensive, and could be improvized without too much difficulty under field conditions.

Adhesives

The use of adhesives to join lengths of rail is a new and most interesting concept. The method is being developed in the United States by the American Railroad Curvelining Corporation, using the "Bondarc" adhesive made by the Armstrong Cork Company. Experiments and field trials have been carried out with the adhesive combined with fishplates, and with adhesive alone.

When combined with fishplates, the rail ends and inside faces of the plates are first sand-blasted, using a fine, dust free abrasive, and the adhesive is then applied to these surfaces. The joint is also preheated in order to eliminate curing stresses. Hand held kerosene torches are used to speed the curing period whilst the adhesive hardens. This curing takes approximately twenty minutes, after which the adhesive is set hard. With 132 lb per yd flat bottom rail and the standard American six-hole, 36 inch fishplates, the combination of adhesives and plates gives a minimum shear resistance of 150 tons. In bending tests, moments of plus and minus 180 tons/inches were applied without causing joint failure, and retesting of the joint in shear immediately after bending showed no decrease in shear resistance. Fatigue tests with repeated applied moments of plus 180 tons/inches and minus 90 tons/inches brought about failure after between 800,000 and 1 million cycles, and this shows that vibration is unlikely to affect the glued joint seriously.

One great advantage with this method is the comparative ease with which the joint may be broken should the need arise (e.g. a broken rail). A solvent is used which rapidly dissolves the adhesive.

Glued joints have been tried in service on the Delaware and Hudson Railway, and on the Quebec, North Shore and Labrador Railway. They have been found adequate in temperatures of -7°F with about 2 million tons of traffic passing over them every month. Experience is also reported to have shown that after the adhesive has set hard, the bolt tension in the fishplates becomes unimportant to the effectiveness of the glued joint.

Apart from the great possibilities which this method opens up for the provision of long continuous rails, its application to structural steelwork generally is obvious, and in fact development in this field is being undertaken in America. The main need for the future is a ready means of testing and proving glued joints. As yet non-destructive testing is not possible.

Machined joints

The last method to be mentioned is the machined joint employed by London Transport. The method was developed before the last war when long continuous track was first used on the Underground. At that time it was considered that thermit welding was not sufficiently reliable, so both railends and fishplates were carefully machined, and with circular instead of oval fishplate holes a very rigid joint was produced. The advantage of the method, apart from the virtually certain reliability of the joint, is the ease with which joints may be broken. On the other hand, the cost is greater than thermit welding, and the possibility of wear taking place is still present.

Transportation, Laying and Maintenance of Long Continuous Rails

Transportation

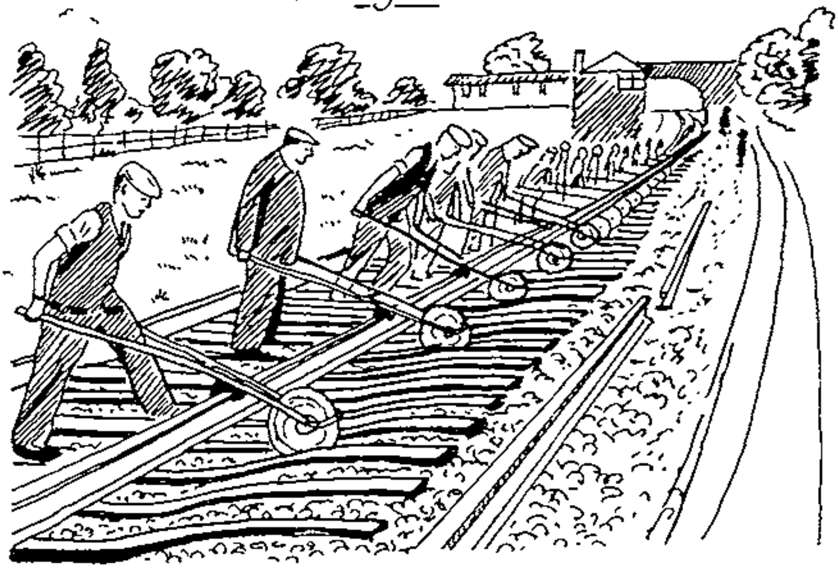
For plain track it has been shown above that normal practice is to fabricate long rails of up to 300 ft in length, and to join these *in-situ* into lengths of up to half a mile. The transportation of 300-ft rails presents no great difficulty as most types of reasonably close-coupled flat wagons can be adapted to carry these long lengths.

The main modification required to ordinary flat wagons is the provision of two or three saddles on each wagon to prevent friction restraining the bending of the rails during navigation of curves, and side posts to help to contain the rails. Groups of rails are chained together at intervals.

Unloading and positioning

On arrival at site, rails can either be off-loaded sideways, using short lengths of greased channel or old rail, or end off-loading can be used. For the latter method the ends of the long rails are attached by SWR or chain

Fig. 15.



GANG USING RAIL BARROWS TO MOVE LONG RAIL INTO POSITION ON CONCRETE SLEEPERS.

to the track and the train pulled away, leaving the rails in the four-foot way of the track on which the train is standing. A variation of this method, in which the rails are laid directly into the fastenings is described below.

Long rails resting in or at the side of a track may be lifted and moved into position by means of rail barrows. Details of these barrows are shown in Fig 15.

It will be seen, therefore, that it is comparatively easy to transport, offload and position long rails in cases where an existing track is to be re-railed, or where one track exists and a new one is to be laid alongside. In cases where new single line is to be constructed the problem is much more difficult. As this question of new single line construction has great military significance, it is discussed in greater detail below.

Connecting long continuous lengths

There is no reason why joints between long continuous rails of half a mile or so cannot be made with ordinary or heavy duty fishplates, provided the temperature range is limited. However, it has been shown that for stability most types of track must be restricted to a temperature range of about 50°F, and if this range is likely to be exceeded the lengths must be periodically de-stressed. With de-stressing the end movements are quite likely to be large. For example, assume a continuous rail of half a mile is laid and secured during the winter at a temperature of 30°F. By the following spring rail temperatures will be reaching 60°F with the possibility of later temperatures in excess of 80°F. The rails will, therefore, be de-stressed, say at a temperature of 50°F. At this temperature the extension over the length of the rail (if free to move) would be

$$L \times q(t_2 - t_1)$$
$$= 2640 \times 12 \times q \times (50 - 30)$$
$$= 31680 \times 67 \times 10^{-7} \times 20$$
$$= 4.25 \text{ in.}$$

Even assuming this extension to be equally divided between the two ends, a movement of $2\frac{1}{8}$ inches is too great to be taken up by a conventional joint. In these cases an expansion switch is used.

There are a number of different types of expansion switch in use, all similar in principle. In addition to permitting the fairly large end movement encountered during de-stressing, they serve to take up creep.

The question of creep is often of great importance, as in certain unfavourable circumstances it can become a serious problem with long continuous lengths. The exact causes of creep are complex, vibration playing an important part, but the result is a longitudinal movement of the rail through the fastenings in one direction. It is a common phenomenon with all types of track, particularly on steep gradients where traffic running down the grade will tend to move the whole rail "downhill". A cure can sometimes be effected by fitting rail anchors.

Another advantage of the expansion switch is that, should a breakage or other defect necessitate cutting out and replacing a length of rail, the consequent adjustment at the end of the rail can be easily made.

Figs 16 and 17 show two types of expansion switch.

Maintenance

There is no doubt that provided long continuous track has been correctly laid, maintenance tasks are reduced. The first essential is good ballasting, and the more care taken initially to ensure a good formation and well packed ballast, the greater the reduction in maintenance is likely to be. In Germany it is common practice to strip off and re-grade the entire formation before re-laying with long continuous rails, and all railways try to achieve consolidated, well packed ballast as soon as possible after laying. With such care long continuous track will keep excellent line and level for long periods with a minimum of attention.

The extent to which good ballast can assist stability by resisting sleeper movement has already been shown. The qualities required of ballast are denseness and the ability to consolidate into a solid mass. A heavy, sharp stone is ideal, particularly if it is brought well up to the sides and ends of the sleepers and a generous shoulder is provided. Slag, and to a lesser extent, ash, will also give satisfactory results if well consolidated.

One interesting point which arises from this requirement of denseness in ballast is that dirty ballast is better in this respect than clean. Particles of dust and grit, together with oil and grease deposited by traffic, have a grouting effect and increase the ability of the ballast to take compressive load. However, the possible effects of consequential poor drainage on the formation may well outweigh the advantages, and it is certainly better to keep ballast clean.

Mention has already been made of the dangers of jacking up long continuous rails if large compressive forces are locked up in the track. Packing should, therefore, be carried out at temperatures near to those at which the track was laid or, better, mechanical packing employed. A machine such as the Matisa mechanical tamper is ideal as no lifting of the track is involved.

The second maintenance requirement is that fastenings must be kept tight. This is essential with long continuous track, both to prevent longitudinal movement of the rails relative to the sleepers, and to ensure that the track acts as a composite structure in resisting lateral displacement.

Allied to good ballasting and security of fastenings is the need for line and level to be of as high a standard as possible. It has been seen that if a maintenance standard has been assumed for a given track, a factor of safety against distortion can be fixed. Obviously errors in alignment, greater than those envisaged, will reduce this safety factor and, if large enough, will cause buckling. Generally, the absence of joints will materially assist in the maintenance of good line and level.

Rail breakages are unlikely to be more prevalant in continuous track than in conventional. In fact, records of existing long continuous rails in service indicate that the breakage rate is slightly lower than with conventional jointed track. In conventional track, most fractures occur at or near the rail ends, often being associated with the fishbolt holes, and continuous track eliminates this characteristic. On the other hand, continuous rails will invariably carry much higher direct stresses than conventional, and when bending stresses due to wheel loads are added to these the resultant maximum stress will be much nearer the fatigue limit.

Should a fracture occur, the fastenings (if tight) should ensure that the resulting gap is not a large one, and repair is usually affected by cutting out a length on each side of the break and welding in a new piece of rail. A special fishplate, using clamps instead of bolts, has been developed to provide a "first-aid" joint at the point of breakage. In France a stock of these is kept by each length gang.

Welding of Yards and Sidings

The problems encountered in welding sidings are little different from those met with in plain line. The main differences may be summarized as follows:—

(*a*) The standard of maintenance in sidings will be generally lower than main line.

(*b*) The length of individual sidings will not be very great.

(*c*) Most curves will be relatively sharp.

(*d*) In yards where track circuiting is used there will be a high proportion of insulated joints.

Unless the sidings are exceptionally long, (*a*) and (*b*) above will tend to cancel out. Therefore, provided the standards of maintenance and ballasting are reasonable, it should be possible to weld sidings completely, leaving ordinary fishplated joints at each end without the necessity for expansion switches. However, this would require welding and fastening down to be carried out at a time of near average temperature. If the fastening down must be done at a temperature much above or below the mean, it will be necessary to de-stress the track later, and without expansion switches this will probably entail adjusting the length of the continuous rail by cutting and welding in a closure rail.

The presence of insulated joints may also present a problem, as these joints are of considerably lower strength than ordinary steel fishplates, particularly in tension. If it is possible to keep the tensile stresses in the track low (by de-stressing or laying at a time of below average temperature) then the use of heavy duty insulated plates will be satisfactory. A very strong

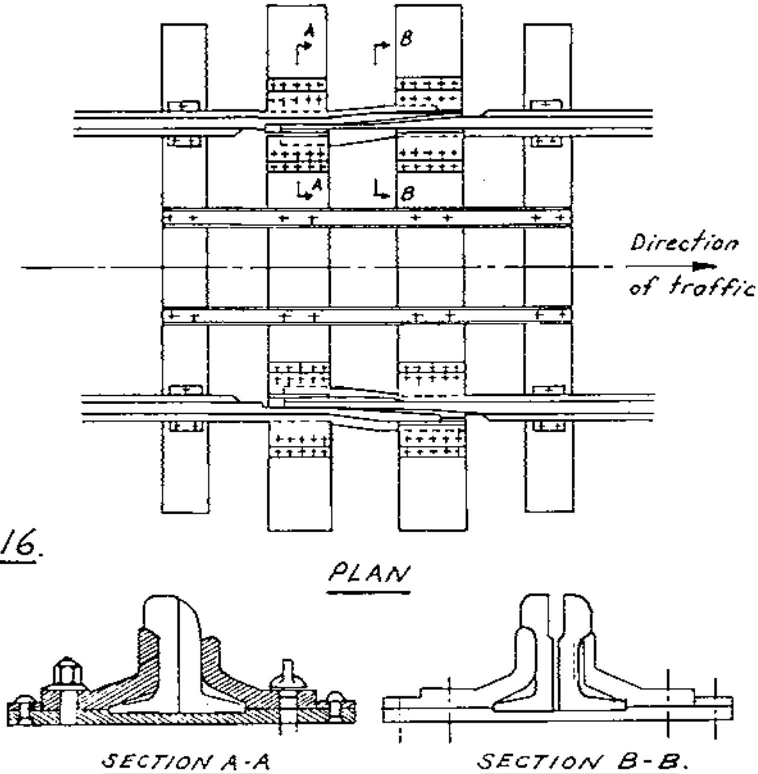
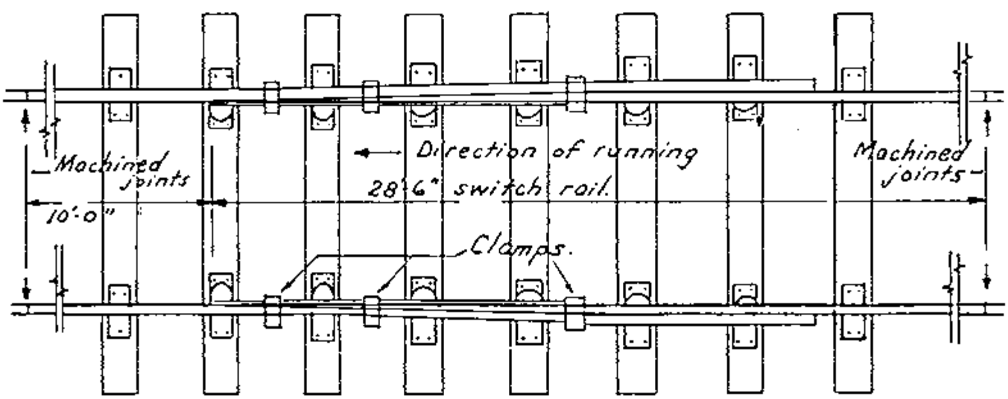


Fig. 16.

EXPANSION SWITCH – FRENCH RAILWAYS.



EXPANSION SWITCH – LONDON TRANSPORT.

Fig. 17.

R

insulated fishplate with a steel core has been developed by London Transport for use with long-welded track, and this has proved completely reliable.

As curves in yards and sidings will nearly always be of sharper radius than that permissible with continuous track they should be constructed with conventional jointed track.

Although sidings are not subjected to high speed loadings, they frequently have to take a high traffic density, and wear is often heavy. Elimination of joints will certainly help to reduce maintenance costs and prolong the useful life of the track. British Railways are now increasingly using welding in yards and sidings, and the new marshalling yard at Margam where, with the exception of insulated joints, nearly forty miles of track in the sidings is welded up solid, is an outstanding example.

Economies Achieved with Long Continuous Track

Although the initial cost of installing long rails is higher than that of conventional track, there is little doubt that an overall saving is achieved. This saving is assisted by the following factors:—

(*a*) Maintenance is decreased.

(*b*) The economic life of rails is increased by the elimination of rail end batter.

(*c*) Fewer sleepers are required. (Sleeper spacing is reduced at joints in conventional track.)

(*d*) The cost of fishplates and bolts is saved.

The actual extent of the savings obtained will depend on many circumstances. For example, most railways using long continuous track do not reduce the manpower in permanent way length gangs. The time saved by not having to attend to joints (and this can be very considerable) is used to improve the general standard of track maintenance. However, at the International Railway Congress held in Madrid during 1958, an attempt was made to assess the average saving. Representatives of more than a hundred railway systems of fifty different countries were asked before the conference to estimate the percentage saving on their own system, and during the Congress the results were pooled and analysed. Estimates of the increase in economic rail life varied from 20 to 50 per cent, and the least optimistic authority placed the overall saving in maintenance costs at 15 per cent.

To summarize therefore, it seems established that long continuous track will last longer than conventional track. The cost of first-class conventional track is in the region of £17,000 per mile, and with an average life of ten years, this represents an annual depreciation of £1,700 per mile. If long continuous track lasts for only twelve years (it will probably last considerably longer) then the annual depreciation drops to about £1,420 per mile. Taken over the original ten-year period, this represents a saving of £2,800. The additional initial cost of long continuous track over conventional is in the region of £300 per mile, thus showing a nett saving of £2,500 or £250 per annum per mile. If the standard of maintenance is kept only comparable with conventional track, then the reduction in maintenance will provide an even greater over-all saving.

Possible Military Applications of Long-Welded Rails

It is hoped that by this stage the reader will be convinced that long-welded track is not only safe, but also potentially more economical. Military requirements in time of war are less concerned with economies than with speed of construction and savings in manpower. However, before going on to discuss whether welded track can assist in these matters, it should be repeated that in any future war military engineers are almost certain to come up against welded track and should, therefore, know something about the special problems and the requirements involved.

It will be convenient to consider the possible military applications under the various types of track likely to be met in military work.

(*a*) *Single line construction.* This is undoubtedly the most difficult form of track on which to provide long continuous rails, and conventional construction will almost certainly be quicker. It would be possible to devise a method by which rails of several hundred feet length, produced in a depot some distance back from construction rail-head, could be off-loaded and towed into position by tractors. However, the sleepers would still have to be got into place, and the difficulties of the method are such that a saving in time or manpower would be most unlikely. As an alternative, it might be possible to prefabricate completely a number of lengths of track of up to 300 ft, and to mount these on flat wagons. Longitudinal runners would be necessary for the bottom length, and two or three long rails spiked to the wagon decks would probably be suitable. The complete sections of track could then be end off-loaded on to prepared formation. It is possible that with this method a great total length of track could be laid in a short time with a minimum of manpower at the construction site, but the off-loading would undoubtedly be cumbersome. Trials would be necessary to show whether the method could compete with conventional construction.

(*b*) *Single line renewal.* Should this be necessary (e.g. a track with light section rail required to take heavier or faster traffic) the use of long rails might well speed up the work. The long lengths could be prefabricated in a depot, or in a mobile flash-butt welding train positioned close to the work, and the replacement of short rails done very rapidly indeed. The method used is to position the train carrying the long rails at the commencement of the section to be re-railed, and to anchor the first two long rails to the existing track. The train is then drawn back until the first 120 ft or so of rail is lying in the 4-ft way, close to the existing short rails. The first lengths of short rail are then removed from the fastenings and the start of the long rails moved in and secured. The train then draws back a rail length, the next length of old rail is taken out and replaced by long rail, and the process continues until the whole long length is in position. With trained teams, the train can be moved slowly backwards virtually without stopping, and North Eastern Region of British Railways, who have developed the method, have achieved continuous re-railing over a long distance at a speed of about thirty feet per minute.

(*c*) *Doubling existing tracks.* Where an existing single line track is to be doubled up, long rails again could speed up the work. With the new formation prepared, sleepers could be off-loaded from a train and positioned at correct spacing, and the long rails side off-loaded on to the sleepers. The rails could then be moved into the fastenings by rail barrows. Although direct comparisons are difficult, it is quite likely that this system could improve on the timings obtained by laying track in prefabricated short lengths. The manpower requirement, however, would be increased.

(*d*) *Maintenance.* If long rails were used as indicated above, maintenance commitments would be reduced. On military lines carrying a large volume of traffic at high densities, this might be a very important consideration.

(*e*) *Ports and harbours.* Continuous welded track, with consequent reductions in maintenance, is particularly suitable for use in ports, where the track is often built into surfaced areas. This building in greatly increases the lateral rigidity of the track, and removes practically all danger of buckling.

(*f*) *Peacetime applications.* In peacetime the question of economy arises, and enough has been said to show that a real saving in maintenance and track life can be gained by the use of continuous long rails. The Army has a considerable length of track in depots and sidings both in this country and abroad, and the maintenance commitment is large. It is considered that should new depots be required, or the renewal of existing installations become necessary, serious consideration should be given to the specification of continuous welded track. By using this modern form of construction economies would be achieved, and valuable experience gained by the Army.

(*g*) *Conclusion.* Apart from the economic advantages which would accrue from the peacetime use of long rails in military depots, it is unlikely that widespread use of such rails would bring any great advantage in wartime. Each situation would have to be judged on its merits. Where rapidly constructed track is required, and low quality can be accepted, conventional methods will probably still provide the best solution; where track approaching peacetime civilian standard is required, or where civilian equipment for fabrication and laying of long rails is available, this construction might well score on speed of laying and reliability.

Bibliography

1. *Design, Installation and Maintenance of Long Welded Rails*, Dunton and Brinsmead, Institution of Civil Engineers, January 1948.

2. *Site and laboratory work in connection with the development of long-welded rail track on the Western Region of British Railways*, Rhodes and Dart, Institution of Civil Engineers, March 1957.

3. *Long-welded rails in France*, Levi, Institution of Civil Engineers, October 1957.

4. *Long-welded rails*, Alley, Permanent Way Institution, April 1958.

5. *Railway Civil Engineering in the U.S.A.*, Permanent Way Institution, December 1957.

6. *British Railway Track*, second edition 1956, published by the Permanent Way Institution.

7. *French Railways Today*, Vivian Rowe, published by Harrap.

Acknowledgements

Fig 9 is reproduced by kind permission of A.1 Electric Welding Machines Ltd, Rose Street, Inverness.

Figs 11, 12, 13, and 14 are reproduced by kind permission of Thermit Welding (Great Britain) Ltd, Rainham, Essex.

Theoretical and experimental work described in the article is based largely on the three papers published by the Institution of Civil Engineers numbered 1, 2, and 3 in the Bibliography. The author is indebted to the Institution for permission to quote from these papers. He also wishes to express his thanks to the Chief Civil Engineer, London Transport, for arranging visits, etc, and to the Chief Civil Engineer, Western Region, British Railways for much assistance during his attachment to the Region.

Minimum Force

By MAJOR J. CATCHPOLE, RE (TA)

DURING annual camp 1960, 577 Construction Squadron RE (TA) carried out a series of demolition tasks on unreinforced structures. Our aim was to determine the minimum explosive required to reduce the buildings to rubble, at the same time limiting noise and blast. The method to be used was as described by James Lorimer BSc in a working paper on "Some Uses of Explosives in Civil Engineering" (27 Nov 45); higher authority had laid down a limit of 10 lbs per blow.

If successful, clearly not only would we minimize damage to nearby property and limit annoyance to civilians; we would also increase the range of targets we could tackle in peacetime training.

TARGET No. 1

A brick building (8 ft by 12 ft internal dimensions) with no roof, constructed of bricks and mortar on a concrete base, the whole in very sound condition. The walls were 14 in thick and the height 8 ft.

METHOD OF ATTACK

Boreholes at 2 ft distances and 1 ft 6 in above the base were drilled at a downwards angle of 30° to a depth of 8 in. This gave a total of 20 boreholes. Additional holes were drilled in two adjacent corners to determine whether the strong bonding of the brickwork would require extra demolition. The remaining two corners were not attacked in this way.

Each borehole was filled with 2 oz of plastic explosive and a 1 oz GC primer. The whole was connected by a det cord ring main, using one Y joint for two holes (spare end into 2nd hole). The charges were well tamped with mud and sheep dung. Initiation was electrically and by safety fuse.

Total explosive used 4 lb 2 oz, as compared with over 18 lb for RESPB methods.

RESULTS

Completely successful; noise was only slight and blast negligible. Telephone wires almost directly over the target were undamaged. Sheep some 100 yds away appeared to take no notice. The explosion appeared to shatter the base of the walls, cracking them upwards. The walls were lifted into the air a few inches and fell, breaking under their own weight, the mortar already having been weakened by the initial blast.

It was interesting to note that in the corners where the additional charges had been placed, the effect was extra lift with less vertical shattering, which resulted in fairly large pieces of brickwork remaining unbroken after the fall.

However, all brickwork was in such a state that it could have easily been made rubble in a short time with hammers.

TARGET No. 2

A terrace of eight derelict quarry-workers cottages which appeared to have been gutted by fire. No roofs or upper floors remained in the buildings, which were from 20 ft to 25 ft in height.

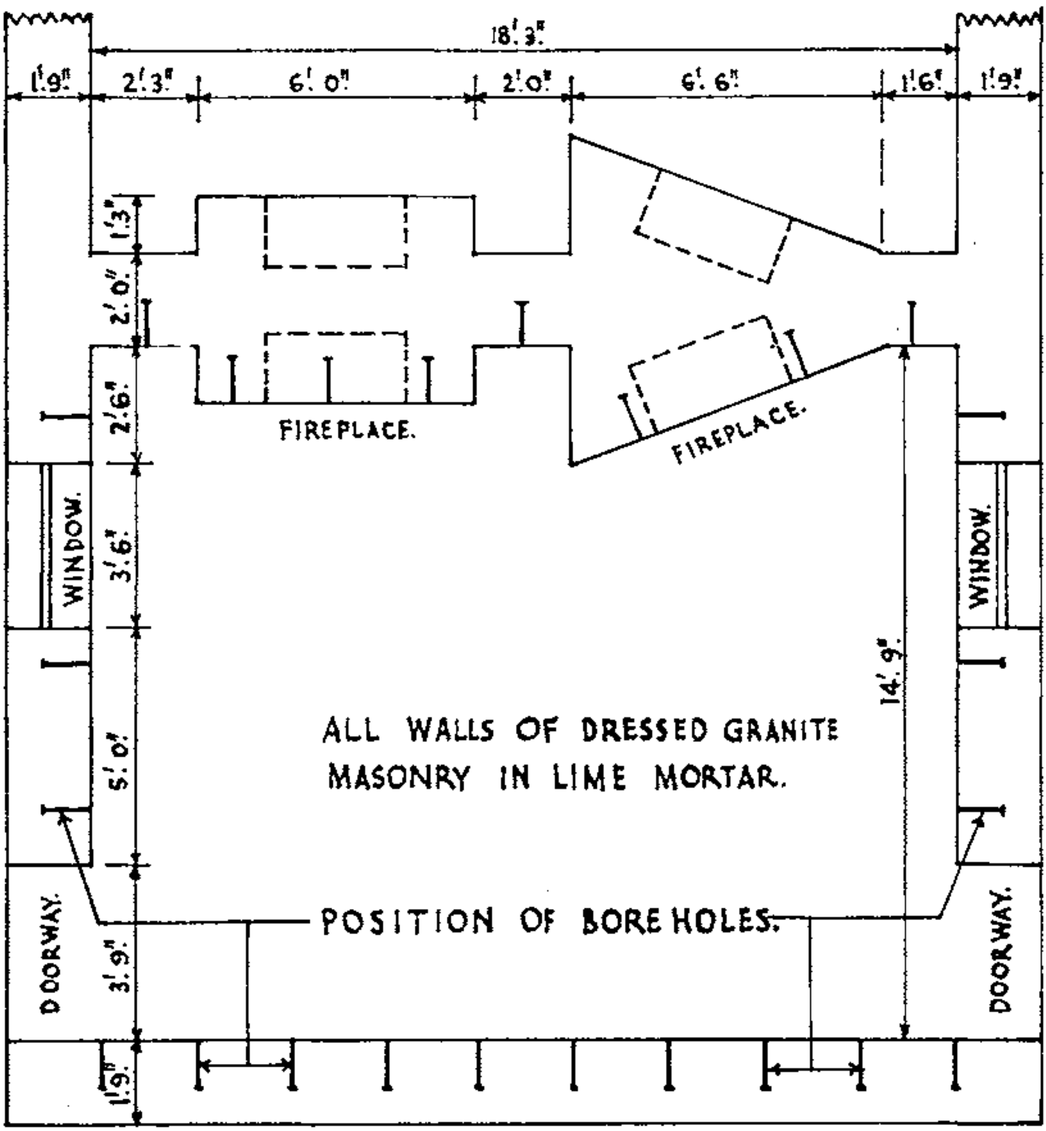
The construction was of irregular size granite blocks, bonded by lime-mortar. Window sills, door lintels and mantelpieces were of granite slabs and several of these latter were in turn supported from the floor by similar granite slabs. (Photos 1 and 2.)

Photo 1. One cottage from west.

Photo 2. Row of cottages from south-west.

Minimum Force 1, 2

ONE COTTAGE.



PLAN AT GROUND LEVEL.

INS. 12. 0. 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. FT.

Boreholes again were used, as for Target No 1. However, due to the internal complexity of the construction of the target, it was decided to attack with a series of demolitions, so that an ultimate successful method could be evolved.

No 1 Demolition

The North end cottage was drilled with boreholes, (see plan). These holes were 2 ft above the base, 12 in deep and at a downwards angle of 30°. The spacing of these holes was as far as possible 1 ft 6 in; however, due to the irregular size of the blocks, it was not always possible to drill holes exactly in position and there was slight variance. Each borehole was filled with 2 oz plastic and a 1 oz GC primer, well tamped with mud. The whole connected by a ring main and fired electrically and by safety fuse. Explosive used for one cottage—4 lb 9 oz.

Result

The effect of the explosion was similar to that on Target No 1; walls appeared to lift, fall and shatter. The end wall and the outside walls broke to rubble. However, the internal wall containing the fire-places remained, this was due to the large granite slabs holding the mantelpieces remaining intact. However, these were subsequently removed by single 4 oz plastic charges placed behind them in boreholes.

No 2 Demolition

The two South end cottages were drilled with boreholes in a similar fashion to No 1 demolition. However, extra holes were drilled around the fire places to get behind the granite slabs supporting the mantelpieces. Boreholes in the outside walls were filled with 2 oz plastic (no primers) and the centre wall with 2 oz plastic on a 1 oz GC primer. All were well tamped, connected by a ring main and fired electrically and with safety fuse.

Explosive for two cottages 6 lb 1 oz.

Result

The end and centre walls, containing the fire places, were successfully demolished. However, the outside walls remained, though badly cracked and out of true. The effect of the reduced charges in these was to make large holes, but not completely cut, and therefore no lifting effect was produced. However, these walls were easily pulled down using SWR connected to a ¾ ton truck.

No 3 Demolition

The next two cottages from the South were now attacked in a similar method to those in No 2 demolition. However, the total charge was now increased in the outer walls to 3 oz plastic and 1 GC primer per borehole.

Explosive for two cottages 6 lb 15 oz.

Result

Satisfactory demolition.

In all three demolitions noise was slight and blast and spreading effect of rubble NIL. In fact for No 3 demolition the writer was standing in the open some 40 yds from the target and felt no effects whatsoever.

Conclusion

The aim was undoubtedly achieved.

Common Suspension Bridge Class 8 100 Feet Span

By 2ND LIEUTENANT C. HOLCROFT, RE

INTRODUCTION

IN June 1960, 30 Field Sqn built an improvised suspension bridge across the river Ems at Warendorf near Munster BAOR.

The bridge was built purely as a training exercise and was later dismantled.

The site was 97 ft across from top of bank to top of bank, and the span of the bridge was 100 ft from centre of tower to centre of tower. Top of bank to water level was a vertical distance of 13 ft.

The stores used were those available in any Field Park Squadron, plus a few special items made by the Workshops Troop.

DESIGN

Each of the two main cables consisted of eight strands of 2-in SWR (larger sizes of SWR were not available in sufficient length) all of which were anchored at each end to a buried "baulk and picket" holdfast (Fig 1).

The suspenders were attached to the main cables by clamps similar to those recommended in *ME*, Vol III, Pt I (Fig 2). At the lower end of each suspender was attached a 1-in dia eye-bolt for securing of the transoms. The eye-bolts (Fig 2) were of sufficient length and sufficiently threaded to allow a 6-in adjustment in the height of the transom.

The transoms were 12 × 12-in, 14 ft long (9 × 9-in could have been used but was not available). The roadbearers were six pieces of 6 × 3-in timber at 2 ft 3-in centres in a staggered and lapped construction (Fig 3). The deck was 3-in thick.

Instead of the usual "A" frames, towers 6 ft square and 10 ft high were built. There were two reasons for this.

The main cables were passed over two "Plain Bailey Rollers" on each pier, thus the horizontal reaction would be small.

To give the men practice in this type of construction, which is similar to the construction required for piers in normal improvised timber bridge work.

Construction

There were no undue difficulties in constructing the towers.

The cables were fabricated complete with suspender and eye bolts on the home bank. This is a job which takes some considerable time and it was fortunate that we commenced this work as soon as we arrived on site, thereby avoiding a hold up at a later stage. The complete cables were then stretched across the river (with the help of two folding boats) and lifted on to the "Bailey" rollers. The ends at the far bank were now passed round the baulk holdfast and secured by means of double throated clamps. The ground on this side of the river was a very loose dry silt, and since the sides of the hold-fast holes continually fell in whilst being dug it was impossible to lay the baulks against firm bearing. The baulks were therefore placed in the bottom of the holes at a depth of 4 ft 6 in and ten park pickets were driven in in front of each baulk. The space now left in front of each baulk was packed up to firmer bearing with timber (Fig 4). This being the case it was necessary to make an allowance (i.e. a decrease) in the distance from the centre of the piers to the first suspender, since the baulk holdfasts were bound to move a little when taking the load fully for the first time.

The required final sag in the main cables was 10 ft, it was decided therefore to tension the cables initially to a sag of 8 ft. The allowances catered for here were as follows:—

Permanent stretching of new SWR when loaded
Elastic stretch
Movement of the holdfasts when coming under load for the first time.

The cables were tensioned from the home side, a different method being used on each cable.

The outside threes of the eight cables were secured to two 7.5 ton shackles, the remaining two being also passed round a shackle. Three pull-lift jacks in line were attached to the holdfast by means of an SWR strop. The upper pull-lift jack was hooked to one of the shackles. The three jacks were now taken in to the fullest extent. The shackles were now temporarily held by an SWR loop round the holdfast whilst one of the jacks was removed. The remaining two jacks were now extended and attached to the shackle and the performance was repeated. When a sag of 7 ft 6 in approx had been achieved, the three shackles were attached by means of SWR to the baulk holdfast. The jacks were now taken away and the SWR attachment gave sufficiently to increase the sag to 8 ft.

The shackles were fastened to the main cables in the same manner as above. About twenty feet back from the shackles a suspender clamp was fixed to the main cables to enable a further length of SWR to be attached at this point to the Michigan LW tractor. The tractor was now driven away from the river thus hauling up the main cable. This time it was estimated that after fixing the shackles to the holdfast baulk and releasing the attachment to the

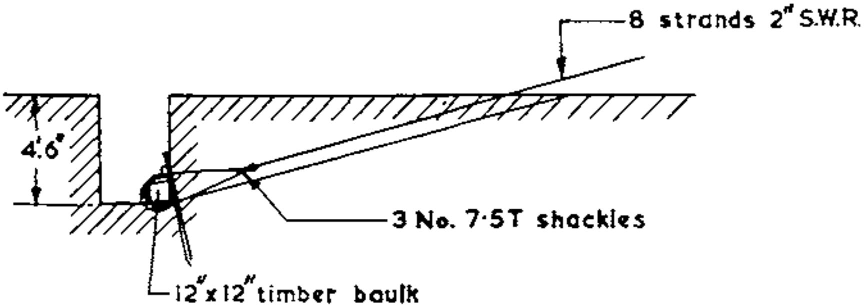

8 strands 2" S.W.R.
4'.6"
3 No. 7·5T shackles
12"x12" timber baulk

FIG 1

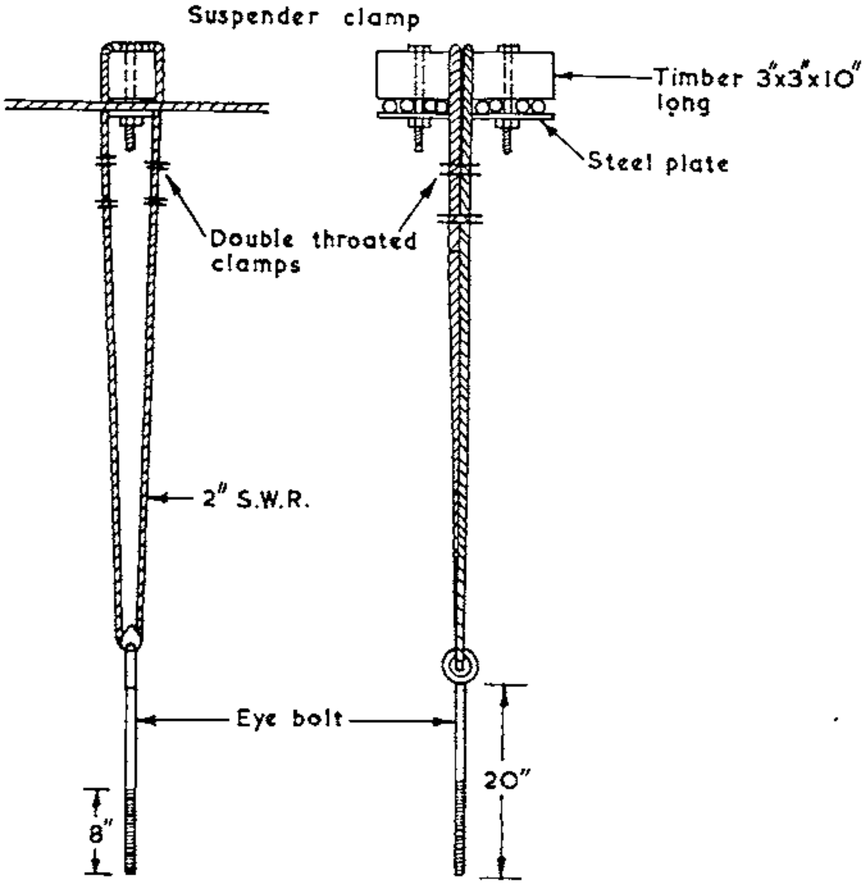

Suspender clamp
Timber 3"x3"x10" long
Steel plate
Double throated clamps
2" S.W.R.
Eye bolt
8"
20"

FIG 2.

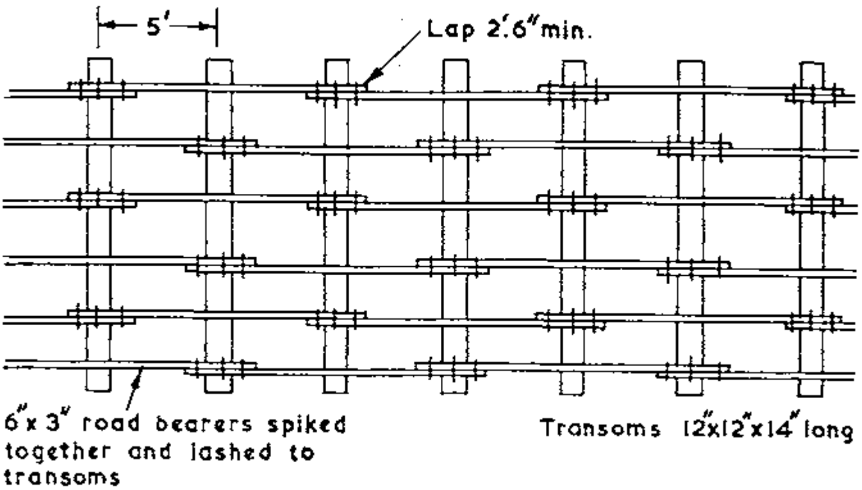


FIG 3.

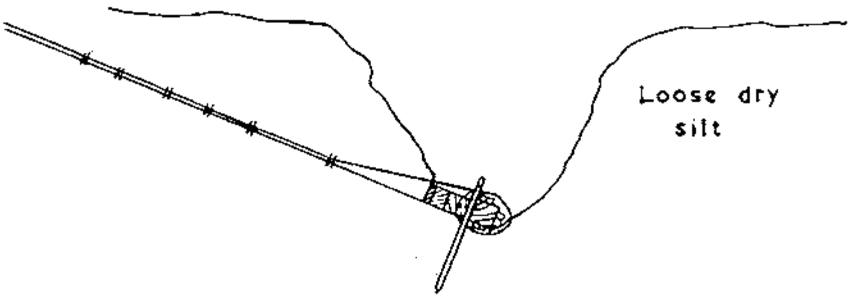


FIG 4

LW tractor the sag of the cable would increase by 1 ft. It was therefore held at a sag of 7 ft whilst being attached. This proved to be reasonably correct and only minor adjustments were now necessary.

An interesting practical point arose here. In plan the two main cables formed curves, their centres being approximately the width of the roadway at the midspan of the bridge. This means that most of the suspenders are inclined to the vertical when viewed along the length of the bridge. It was found necessary to cause the main cable to lie at an incline by increasing the tension of the inside four of each set. The pull on the suspenders was now right angles to the clamp attachments (Fig 5).

The clamp attachments could also be improved by having the steel plates made with a vertical turn up of about one inch at each end. This will prevent any tendency of the outside cables to jump out of the clamps.

No undue difficulty was found in fixing the transoms. Two methods were used. The transoms nearest to the bank could be lifted on to the eye bolts and fastened quite easily. The three nearest to the home bank were fitted first.

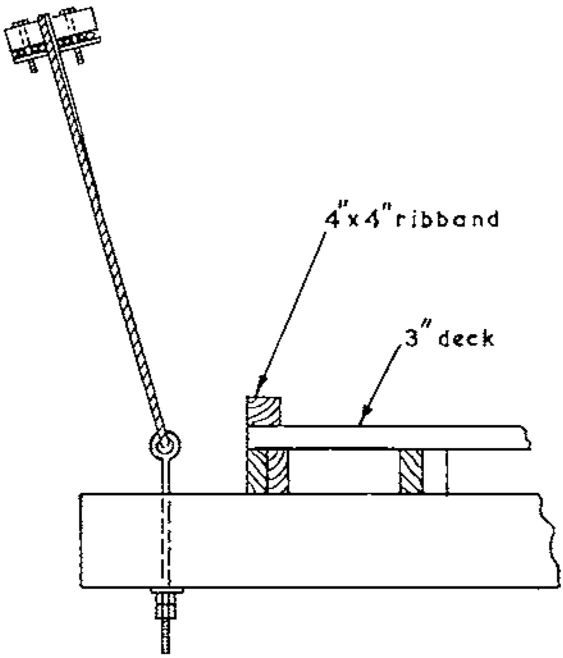


FIG 5.

Using the transoms already fixed, the next transom was cantilevered out. One man then walked along the transom and attached the eye bolt to that end. Cordage was attached to the free end of the transom, passed through a snatch block (hanging from the main cable adjacent to the required suspender) and held by a team on the bank. The weight of the transom was thus taken whilst the second eye bolt was secured.

This method is the same as that described above except that snatch blocks and cordage were used for both ends of the transom.

Not a little difficulty was found in screwing the nuts up the eye bolt thread. This was because the threads were new and had never been used before. It would have been well worth it to run the nuts up and down the thread in the store beforehand. This is a point worthy of note and would in this case have saved us two to three hours.

The decking down was a simple and straightforward procedure.

Live Loading

After completion of the bridge a 3-ton truck was driven across twice in order to test the construction and enable the baulk holdfasts to settle to their final position.

An inspection now revealed that the home baulk holdfast had each moved 1-in, and the far baulk holdfast, which it will be remembered was in bad ground had moved 4-in; also the final sag in the main cables was now 10 ft 4 in. This extra 4-in could quite easily have been adjusted at the home fastenings, but since it was of no consequence it was left.

WORKING STRENGTH AND TIMES

Two towers completed All main cables and suspenders cut to length	½ day
Two more towers completed Baulk holdfasts complete Main cables erected Final tensioning of main cables	1 day
One bankseat complete Thirteen transoms fixed 20 ft of decking complete	1 day
Remaining bankseat complete Six more transoms fixed Decking completed Bridge tested	½ day

The above work was carried out with a working strength of thirty men, assisted by the Michigan LW tractor which did all the excavation.

The work was supervised by three sergeants who are included in the above working strength.

TRANSPORT

The materials required for construction were carried in five 3-ton vehicles with 2 ton trailers.

CONCLUSION

The exercise was highly successful and held the interest of all the men. Furthermore it was one of those rare occasions when almost every item held in the Troop G 1098 stores was used, including all the compressor equipment. As a training exercise it was also extremely valuable, in giving the men practice in basic and more advanced field engineering.

The Corps and Works

By MAJOR J. C. D. MONTGOMERY, BA, AMICE, RE

THE Chief Royal Engineer recently received the following letter from the Secretary of State for War, the Right Honourable J. D. Profumo, OBE, MP:

"On the 12th August 1960 responsibility for Works Services in the British Army of the Rhine passed from the Chief Engineer to the Command Works Officer and the Royal Engineers finally laid down their peace-time responsibility for housing the Army. This act brought to an end a function performed by the Corps of Royal Engineers and, before them, by the Board of Ordnance since the Army's earliest days.

"I and my colleagues on the Army Council are conscious of the efficiency, energy and loyalty with which this responsibility has been discharged at all times, and often in the face of difficulty, and would not wish the occasion to pass without a mark of our appreciation of the work of all ranks of the Corps of Royal Engineers."

To which the Chief Royal Engineer replied:

"I am most grateful to you for your letter of appreciation of the work of the Corps of Royal Engineers over so many years, in discharging their responsibilities for the housing of the Army in peace-time. I can assure you that this recognition by yourself and your colleagues on the Army Council of the value of their work to the Army will give great satisfaction to all members, past and present, of my Corps."

It is felt that, in view of this event, the present is a proper moment at which to review the achievements of the Corps in this field. A summary of these achievements is, therefore, set out below.

There have been military engineers in Britain since the days of the Norman invasion in 1066.

From then a few Engineers were permanently employed by the Crown, mainly on fortification works; they were known as the "King's Engineers". These Engineers subsequently came under the Office of Ordnance, which originated in the fifteenth century, and was given a definite establishment in 1589. It was not, however, until 1683 that a Royal Warrant properly defined the organization of the Board of Ordnance, and set out rules and regulations for its government under a Master General, under whom came the Chief Engineer and Assistant Engineers. A similar organization was subsequently set up in Ireland under the Irish Parliament. This remained until the English and Irish Parliaments united in 1801, when the Irish Board of Ordnance ceased to exist and the Chief Engineer in Ireland came directly under the English Board of Ordnance.

Until a Standing Army came into being at the Restoration in 1660 there was little incentive to build barracks, and barrack accommodation at the end of the seventeenth Century was practically limited to castles and other fortifications. Troops not stationed in these were encamped or billeted in ale houses. As a result of the English Parliament's dislike of the Standing Army, the process of barrack construction in England in the eighteenth Century was slow and it was the Irish Parliament that voted the first large sum of money (£25,000) to provide barracks. The first important ones, the Royal Barracks in Dublin, were built in 1705–09 under the supervision of the Irish Chief Engineer, Lieutenant-Colonel Burgh. The next major construction was in Scotland where barracks of a rather austere nature were constructed in various places in the Highlands for security forces after the 1745 Jacobite rising had been suppressed.

In 1792 the Napoleonic Wars created a demand for a great expansion in barrack accommodation in this country and the British Government, with the idea of speeding up construction, decided to transfer responsibility for the construction and upkeep of the barracks for the Cavalry and Infantry, but not for the Artillery, the Engineers and other services under the Board of of Ordnance, to a new civilian Barrack Department under a Barrack Master-General. During this period, in 1802 to be precise, the Chief Engineer of England was promoted to become the Inspector General of Fortifications. Although the civilian organization succeeded in building the barracks required, there was a considerable loss of financial control and efficiency and after the wars against Napoleon were over the Duke of Wellington, who had been appointed Master General of Ordnance, advocated a reversal of policy. This was approved and in 1822 an Act of Parliament abolished the Barrack Department and the Royal Engineers resumed their responsibilities for the construction and maintenance of all barracks under the Board of Ordnance. Subsequently, in 1855, the Board of Ordnance was abolished and its duties transferred to the Office of the Secretary of State for War.

The next expansion of barrack accommodation was caused by the Crimean War when the great military centres of Aldershot, Colchester, Shorncliffe and the Curragh were built as hutted camps, which were later converted into permanent barracks. The events of the Crimean War also so stirred the public interest in military hospitals and the barrack accommodation of soldiers that a Royal Commission was appointed. As a result of its report a Barrack and Hospital Improvements Committee was set up in 1862 (this was later called the Army Sanitary Committee, and in 1904 it again changed its name to become the Medical Advisory Board). As a result of these activities new military hospitals were built at Netley and Woolwich, and great improvements were made by the Royal Engineers in the designs and amenities for hospitals and barracks. In 1872 many additional barracks had to be provided to meet the requirements of Lord Cardwell's Army reorganization scheme and new barracks and Regimental Depots had to be built all over the country. Construction of these was completed prior to the South African War but, even so, further accommodation had to be provided for the Army then being trained. In 1899, therefore, £1,600,000 was voted for the construction of barracks for eight Infantry Battalions and other units at the new military station of Tidworth on Salisbury Plain. Further projects for construction of Cavalry and additional Infantry Barracks at Tidworth were initiated in 1901. After this war much accommodation also had to be built for the British Army Garrison left in South Africa.

In 1904, as a result of the Esher Committee, there were further changes in the Works Organization. The Inspector General of Fortifications was redesignated as Director of Fortifications and Works and he, with the Corps, remained responsible for military works abroad. At home the construction and maintenance of Barracks was transferred to a new civil Barrack Construction Department under a civilian Director. This arrangement, however, did not work well and in 1908 the Director of Barrack Construction was made responsible to the Master General of Ordnance, while the Director of Fortifications and Works became adviser to the Army Council on all barrack construction. This last arrangement produced good results in the progress in design and provision of barracks and married quarters, but the civil Barrack Construction Department did not prove satisfactory and in 1917 the Royal Engineers again resumed full responsibility for works.

It will be realized that throughout this period the Royal Engineers had to provide fortifications and accommodation necessary for the many overseas garrisons. The following are a few examples of the type of work involved.—

(*a*) in 1907 the Royal Engineers had rapidly to rebuild the barracks in Jamaica which were destroyed by earthquake;

(*b*) new barracks for the Army of occupation had quickly to be built in Egypt when Britain assumed responsibility for that country;

(*c*) in India work went on continuously on the construction of new barracks and the improvement and maintenance of those in existing cantonments.

The next large programme of new construction came after World War I. Initially this was required to replace the accommodation which had been handed over in Southern Ireland and entailed the construction of the new military centre at Catterick. Apart from barrack accommodation, great new Ordnance Workshops and Depots had to be built and fresh requirements, due to the mechanization of the Army, had to be met. Furthermore the modernization of barracks was accelerated and in 1936 the new "Sandhurst Block", which included under one roof barrack rooms, dining rooms, bathrooms, etc., was originated for soldiers; central heating became a feature of the new construction; and more and better married quarters were built.

Meanwhile some outstanding works were executed by the Royal Engineers abroad. In India the great new cantonment of Razmak was built in the heart of Waziristan, and after the disastrous earthquake at Quetta in 1935 new earthquake proof buildings were designed and constructed in the succeeding years. In Malaya and Singapore modern barracks arose and the Changi cantonment was constructed.

A further expansion took place just prior to World War II when a large number of hutted camps had to be built in the UK to meet the increase in size of the Army as a result of the call-up of the "militiamen" for National Service.

During World War II, in 1941, an Engineer-in-Chief was appointed at the War Office and given executive control of the Works Service under the control of the Quartermaster General. The Director of Fortifications and Works thus became subordinate to the Engineer in Chief. The first E-in-C was Major-General C. J. S. King* and he, to improve control, brought into being the central accounting system for works. During the war the Works Services were very heavily committed both at home and abroad. In India the enormous expansion of the Army necessitated much new storage, workshop buildings and hutted barracks. In Egypt the Tura Caves were converted to Army use and very many camps, depots, workshops, roads and railways had to be built for the huge Middle East Base set up during the War. After the war, in 1947, the status of the Director of Fortifications and Works was reassessed and as a result his rank was raised to that of Major-General. His responsibilities included military works at home and abroad, until the appointment was abolished on the transfer of military works to the new civilian Works Organization under a civilian Director General in 1959.

Between World War II and the transference of responsibility for works to the new civilian organization, some notable achievements are credited to the Corps. These include the rapid construction of large camps, including churches, cinemas and shopping centres in Palestine, before we evacuated the country; the rapid construction of hutted accommodation to house the GHQ MELF units and families, stores and workshops that had to be withdrawn from the Delta to the Canal Zone of Egypt in 1946–47; the construction of a large storage depot at Mackinnon Road, near Mombasa, employing Italian prisoners of war and large gangs of African labour; the construction of the British Army Headquarters in Germany; the building of the British Headquarters and Base in Cyprus at Dhekelia and Episkopi; and the continued modernization of barracks and construction of married quarters, both at home and abroad. In addition the Royal Engineers started the construction of the Gurkha Depot in Nepal, the new cantonment in Malacca and the new military cantonment at Kahawa in East Africa, the construction of all of which is still being supervised by the Corps.

The long established duty of the Royal Engineers to house the Army led inevitably to the employment of the Military Engineers in great works of

*Now Lieut-General Sir Charles King, K.B.E., C.B., Colonel Commandant RE (rtd) civil development in the pioneering days of the countries of the Empire and Commonwealth. Such work was carried out by the units of the Corps, by individual serving officers, who were seconded to the Public Works Service and, in addition, by Sappers on their retirement from the Army, who carried out much outstanding work of this kind. A few examples of the great number of works carried out by Sappers in all these categories are included in the following paragraphs.

Some of the greatest works of the Royal Engineers were in India. These included the following:—

(*a*) Irrigation and Water Works. Among the biggest canal systems constructed in the Nineteenth Century by the Military Engineers were the Western Jumna Canals, Ganges Canal, the Lower Chenab Canal, and Sir A. T. Cotton's Godavery Delta and Kistna and Orissa irrigation systems. In Southern India the 173 ft high and 1,241 ft long Madura Dam was built for the Madura water supply system. The 5,136 ft long Mutha Dam was constructed near Poona, and water supply systems for many important towns, such as Poona, Lucknow and Murree, were all designed by officers of the Corps. Between 1922 and 1933 the Uhl River hydro-electric system in the Punjab which was designed and built by Colonel Battye, included a tunnel which was driven for over 2½ miles through rock and supplied fourteen towns with electricity;

(*b*) Road Construction. The country provided very great scope for this form of engineering and the construction of most of its main roads was carried out under the supervision of officers of the Corps. One of the best known perhaps is the 1,500 mile long Grand Trunk Road from Calcutta to Peshawar, which continues to the Khyber Pass. The roads in Baluchistan, Waziristan and other regions were also constructed under the supervision of RE officers;

(*c*) Railways. Between 1849 and 1929 no less than 41,000 miles of railways were built in India but RE officers were more concerned with their administration and operation than their construction. The best known and most difficult line constructed by the Royal Engineers was the Sibi-Pishin-Quetta line which was designed and supervised by Sir James Browne;

(*d*) Marine Works. The Madras Harbour owes its original design to the East India Company's Military Engineers. In addition the construction of the Calcutta Docks was begun by Colonel Henry Watson as early as 1780. The Bombay Docks and the Causeways used in land reclamation in that area were also the work of the Military Engineers. Apart from this, Engineer officers were responsible for the design and construction of many of the lighthouses on the coasts of India and Burma including the 160 ft high Alguada Reef Lighthouse;

(*e*) Construction of many Public Buildings. These include St. Pauls Cathedral Calcutta, churches, colleges, hospitals and Mints.

The Royal Engineers have also carried out similar work in the other Continents. In Africa this included:—

(*a*) the management of the Egyptian railways;

(*b*) a report by Sir Andrew Clarke (late RE) firstly in 1870 on the condition of the Suez Canal and subsequently on its widening;

(*c*) the founding of the City of Nairobi by Corporal Ellis RE.

In Canada the Sappers are remembered among other things for the opening up of the Rideau Waterway by Lieutenant-Colonel John By, who also founded Ottawa, known until 1855 as Bytown, and for the work by Colonel Moody in laying out the capital of British Columbia and building roads, churches and other public buildings.

The peace-time responsibility for works has now been handed over to the civilian Director General of Works and we have come to the end of another chapter. The book, however, has not been closed, for the Royal Engineers are still responsible for this service to the Army in time of war and for works services in certain conditions under which the civilian organization cannot function efficiently. For this reason courses continue to be run at the SME to train Garrison Engineers, Clerks of Works (these latter courses having been run for the last hundred years), and officers in Civil, Electrical and Mechanical Engineering.

No doubt the Royal Engineers have many chapters yet to write in the story of Military Works.

Engineering and Politics in Jordan

By Lieut-Colonel W. G. A. Lawrie, RE

One of my responsibilities as Military Attaché in Amman was to keep under review all forms of engineering development in Jordan. In more stable countries such things evolve progressively according to economic requirements and can be planned ahead, but in the volatile atmosphere of the Middle East they are at the mercy of changes of government and foreign policy. It may be of interest to trace through the three years which covered the withdrawal of the British Forces in 1957 and their brief return the following year, how political considerations have in some cases prevented the execution of feasible projects and in others forced the adoption of economically questionable ones.

Airfields

Although Jordan, a small and poorly endowed country, already possesses two of the finest runways in the Middle East at Amman and Mafraq, there has been strong political pressure to build yet a third international airport in the Jordan Valley. For many years Amman was important as an R.A.F. staging post. Mafraq was built by the R.A.F. and was still uncompleted in 1957 when they left. H.M.G. has always allowed Jordanian aircraft to land in Cyprus, Malta, North Africa and the U.K. and Jordan has reciprocated by allowing R.A.F. aircraft to land at Amman and Mafraq, but altered strategic concepts and the longer range of modern transport planes have made these two airfields of only marginal value. Although they cost millions of pounds to build we were obliged to hand them over to the anti-western Jordan government of the day at a purely nominal valuation when the Anglo-Jordan Treaty was terminated in 1957.

Mafraq's remote situation makes it useless as a civilian airport and it is too near the Syrian border for comfort. Amman airport, where the Parachute Brigade landed and camped in 1958, is fully utilized for civil and military flying, but most visitors to Jordan want to visit Jerusalem, which has a short runway among dangerous hills and impossible to extend. It is also close to the Israeli frontier which makes it difficult to land there on occasion without infringing Israel's rights. This has led to the demand to build a new international airport near Jericho which could serve both Amman and Jerusalem and would pay for itself with increased tourist traffic. It would also provide employment for some of the many thousands of refugees still living in camps in the Jordan Valley.

There is a clear requirement for an all-weather airfield in south Jordan. Purely military grounds indicate developing the strip at Ma'an, which would also be easy for tourists visiting Petra. But economic and business interests favour improving the Aqaba airstrip and will probably win, although it is only a stone's throw from the parallel Israeli airstrip at Eilat.

Roads

The United States Operations Mission to Jordan originally planned three main routes for the country, based on topographical and economic considerations,—

(*a*) Amman to Jerusalem. This was to link the two principal cities of Jordan, replacing the existing narrow, winding and dangerous route, and was to be built in two stages,—Amman to Kallia on the Dead Sea, and Kallia to Jerusalem. The first stage was completed in 1958 and the second stage is now being planned.

(*b*) Ramtha to Naur. This was to connect the Amman-Jerusalem highway with Damascus for trade and tourist traffic, and should be completed this year.

(*c*) Shuneh to Aqaba. Connecting the main East-West highway with Jordan's only port, by a road running down the eastern shore of the Dead Sea into the Wadi Araba. This was not agreed by the Jordan government and has never been started.

The Amman-Jerusalem highway was clearly essential. The old road, though picturesque, involved a car journey of over two hours. This will be halved when the whole route is complete. The new road is designed on the grand scale with tremendous cuttings and embankments. (Photo 1. shows work in progress in May, 1957.)

The effect of politics on this road was that owing to unrest in the Middle East all Americans in the Operations Mission were withdrawn from Jordan in 1956 before construction started and the work was carried out with very inexperienced Jordanian supervisors and plant operators. The design contravened many of the principles of road making I learnt in the similar terrain of Waziristan. The road was not cut far enough into the hillside but constructed on uncompacted soil. Fills were frequently over 50 ft high with no retaining walls. Cuttings were far too steep and catchwater drainage was neglected. Light shingle was spread straight onto the earth formation and then asphalted. Plant was handled uneconomically and inefficiently and the maintenance and repair organization was inadequate.

The road was officially opened to traffic in October, 1958 and we were all delighted to see that we really could travel at 50 m.p.h. all the way as had been promised. But I was not surprised to notice that the first winter caused

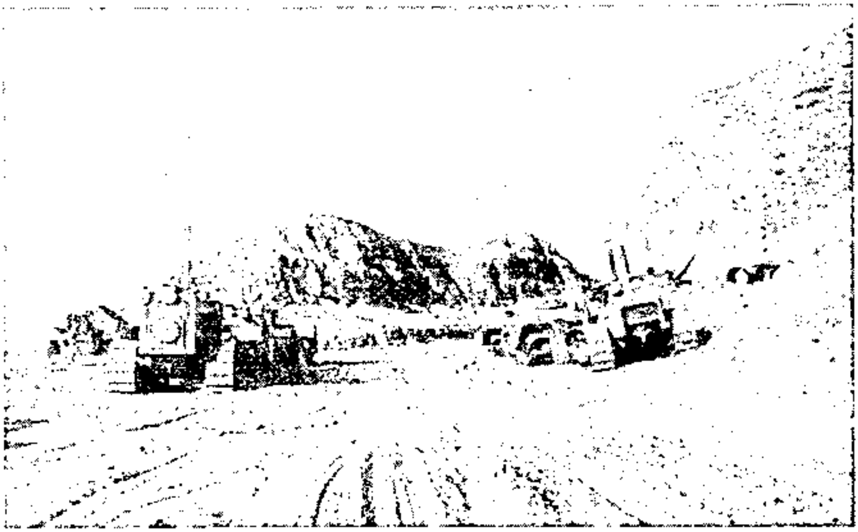


Photo 1. Work in progress on the new Amman-Jerusalem road.

serious subsidences and landslides all along the road. It was bad luck as none of this would have happened if the American engineers had been able to stay and see the work through.

The Ramtha-Naur highway was planned when Jordan and Syria were reasonably friendly, and work began under the anti-western government of Jordan, who were at one time discussing a closer union with Syria. But for most of my stay in Jordan relations were so bad that the Syrian frontier was closed. The Jordan government of 1958 with a new foreign policy tried to get the funds and equipment switched to more immediately useful projects but they were unsuccessful. This road is now nearly finished. It is better built than the Jerusalem road because some of the faults have been put right and American advice is now available, but there is no possibility of it being used to anything like its full capacity as long as there is a state of tension between Jordan and the UAR.

The Jordan Government did not agree to the American alignment of the Aqaba road because it is completely exposed to attack from Israel. The Americans would not agree to provide funds for the construction of a road further west which would be politically and strategically more acceptable. In 1956 HMG agreed to finance the Desert Road from Amman to Ma'an because it was the main L. of C. for the British Forces stationed in north Jordan at that time, but after the termination of the Anglo-Jordan Treaty in 1957 work came to a halt. The contractors were inefficient and dishonest, there was no supervision and funds were not forthcoming. When I drove along the alignment in April, 1958 I saw several large parks of mechanical equipment covered with a thick layer of sand. Some earthwork had been completed but was being dug up again by the culvert contractor. None of the nine bridge contracts had been let. At this time no one was worried. Although Jordan's western and northern frontiers were closed, the Union of Iraq and Jordan had just been proclaimed and all thoughts were directed to developing closer

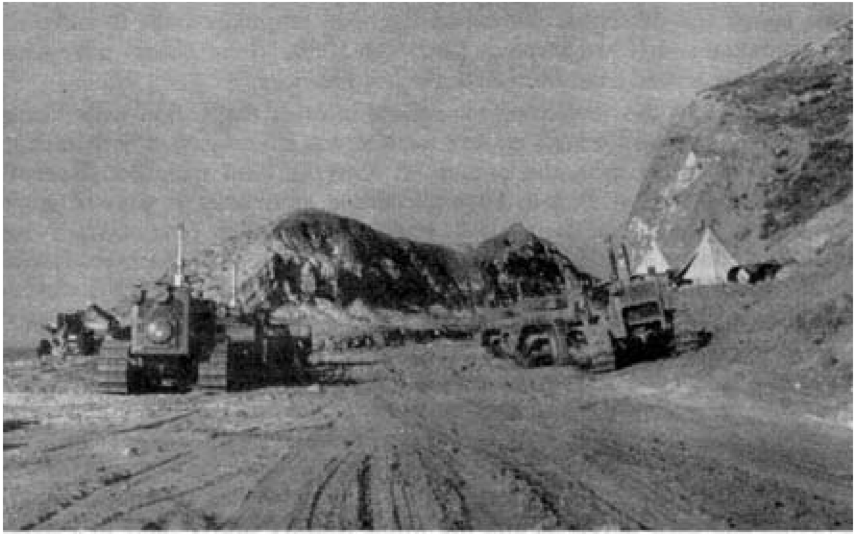


Photo 1. Work in progress on the new Amman-Jerusalem road.

Engineering and politics in Jordan 1

links between the two countries. There was a narrow and inferior asphalt road across the desert via Mafraq to Baghdad originally built to serve the IPC pipeline which ran through Jordan to Haifa. Great efforts were made to improve this road from Amman to the Iraqi frontier.

In July 1958 the revolution took place in Iraq, the Union with Jordan came to an end and Jordan's eastern frontier was also closed. The Parachute Brigade was flown in at the request of King Hussein with Ben Gurion's permission to overfly Israel. They succeeded admirably in stabilizing the situation in Jordan, but their L of C was precarious. The port of Aqaba had inadequate facilities and there was no all-weather road to Amman. Lorries could either use the tortuous, unmetalled mountain road through Kerak, or take the equally hazardous dry-weather track across the desert from Ma'an.

The presence of the British Forces, and the increasing economic need for Jordan to have her own independent port to the outside world, started a new drive to complete the desert road and modernize Aqaba. The troops were withdrawn in November 1958 but the very severe winter which followed provided a fresh impetus. The mountain road was blocked for three weeks with snowdrifts up to 10 ft deep. There was much loss of life among the Bedouin and their livestock, and the whole country nearly came to a standstill. Jordan is completely dependent on oil for cooking, heating and fuel for electric power stations, water supply systems, road transport and railway locomotives, and every drop had to come from Aqaba.

HMG provided generous loans to enable the port of Aqaba to be modernized and the desert road to be finished. British consultant engineers took over supervision of work on the road as well as in the harbour, and before the end of 1960 Jordan should have a fine all-weather road linking Amman and Aqaba.

Within ten years the emphasis in Jordan's principal land connections has thus been shifted from Palestine (as it was) to Syria, from Syria to Iraq and from Iraq to the Gulf of Aqaba. The only link which has not been developed is that with Saudi Arabia. It is not outside the bounds of possibility in the future that closure of the Gulf of Aqaba or closer ties with Saudi Arabia might necessitate the construction of an all-weather road through Bayir to Tebuk to replace the present desert track.

Railways

The Hashemite Railway has also been bedevilled by politics. Originally built as part of the "Drang nach Osten", the line from Damascus to Medina ran through Jordan, and was used extensively by the Turks in World War I for military traffic. T. E. Lawrence was responsible for harassing the railway and destroying stations, bridges and locomotives. The line from Ma'an to Medina is still derelict but it is in use from Ma'an to Damascus, the permanent way, signals and some of the rolling stock being now over 40 years old. A spur was built from Ma'an to Ras en Naqb to take Aqaba traffic, but so far no way has been found of running the line beyond Ras en Naqb and down the 3,000 ft escarpment to the sea.

As long as British Forces were in Jordan the railway had the benefit of Sapper advice and assistance, but once we had withdrawn it went rapidly downhill and by mid-1958, when it was desperately needed to bolster up Jordan's lifeline to Aqaba, it had practically ground to a halt. The Americans generously provided teams of railway engineers to supervise the line and they have produced remarkable results in a very short space of time.

New locomotives were brought from Japan, the only country whose gauge is close to Jordan's 105 cm. Workshops have been set up at Amman and Ma'an. Previously the only workshops were in Damascus, which made it very difficult when relations were broken off with Syria or the UAR. Spares have been ordered for unserviceable locomotives and rolling stock and the staff have been galvanized into action. Traffic and revenue were booming by the end of 1959 to such an extent that vested interests in the lorry haulage industry were seriously worried. Some experts are convinced that the railway can and should be extended to Aqaba harbour. At the moment all goods have to be transhipped at Ras en Naqb and travel to and from the port by road, which is slow and costly. The only real problem is raising the capital. If Jordan can continue its present political stability the money should be forthcoming from international sources. I see no reason why the extension should not be completed within the next ten to fifteen years. It should be possible to finance the interest on a loan from savings in transport costs.

During the short-lived Arab Union there were plans for building a railway from Aqaba to Baghdad. It was claimed that this could be paid for out of savings in freight and insurance through landing goods at Aqaba instead of Basra and so saving ten days in transit time from Europe. Another scheme that has been proposed is to reopen the line from Ma'an to Medina. Saudi Arabia would be a good market for Jordanian fruit and vegetables if better transport facilities existed, but all reports have shown the cost of rehabilitating the line would be prohibitive. Either of these schemes might be revived if required by some future swing of the political pendulum.

A freak of politics is the Jerusalem-Haifa railway. Tulkarm station, where wartime students at the Haifa Staff College will remember doing a Movements Exercise, used to be on this line, but at the end of the Arab-Israel war the station and a few hundred yards of permanent way remained in Jordanian hands and are now derelict. The rest of the line is in Israel and the Israelis have built a short loop 50 yds on their side of the frontier to by-pass Tulkarm and reopen the line to traffic. Another curious place is Battir, a village just south of Jerusalem which is bisected by the cease fire line. The frontier cannot really be said to exist here. The village consists entirely of Arabs. One householder may own allegiance to Jordan and his brother next door to Israel. The village school is in Israel and the children cross and recross the dilapidated and unguarded single strand wire fence every day. The Jerusalem-Haifa line runs straight through the village just on the Israeli side, but in spite of the tension between the two countries which so often has seemed about to boil over, the railway has just kept on running.

Ports

As long as Jordan could rely on using Haifa (up to 1948) or Beirut, there was no need for Aqaba to be more than a fishing village, but the last few years have seen great changes. Closure of the Suez Canal to Israel made Eilat vitally necessary as a port from which she could carry on trade with countries south and east of the Mediterranean and through which she could import oil from the Persian Gulf. In the days of King Solomon, when the head of the gulf was busy with the mining and smelting of copper and the

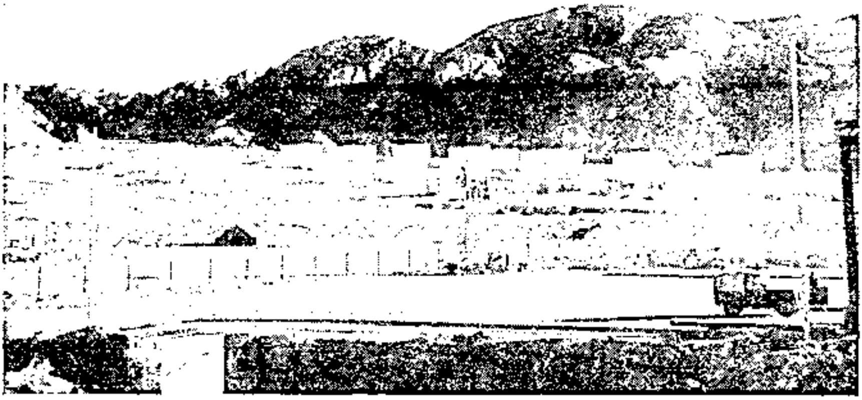


Photo 2. The new oil tank farm at Aqaba.

import of timber from South India, one port was sufficient, but now at either end of a short strip of beach political considerations require two harbours, two airfields and two oil tank farms. The Jordanian port of Aqaba is, of course, not new, but its recent development is striking. In 1952, 50,000 tons of cargo were handled; in 1959, 600,000 tons. This year the total will be higher again. This in turn has meant the construction of new facilities, including modern equipment for loading phosphates which came into operation last December.

The Gulf of Aqaba is so narrow that the territorial waters and fishing rights of the four countries that meet at its head are intricately involved. At present ships stay in the middle and hope for the best, but in the event of hostilities breaking out in which any of the countries were engaged either Egypt or Saudi Arabia could close the narrow straits of Tiran, annoying Israel but strangling Jordan. This was why "O" Force was stationed at Aqaba under the terms of the Anglo-Jordan Treaty and why the port was reopened by us in 1958. Aqaba is now more important to Jordan than ever but will always be her Achilles' heel unless she has the support of a maritime power.

Oil

With no coal, wood or hydro-electric potential Jordan must have oil to survive. A few international organizations hold concessions for oil prospecting, and drilling has been in progress for some years at likely sites with absolutely no results. Here again political factors have complicated a straightforward problem. The old pipeline from Kirkuk to Haifa still crosses Jordan,

Photo 2. The new oil tank farm at Aqaba.

Engineering and politics in Jordan 2

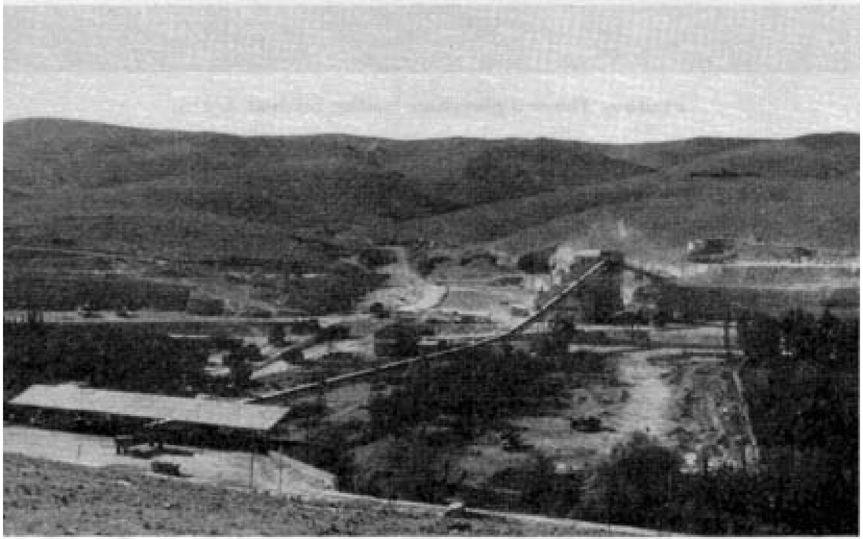


Photo 3. The Ruseifa phosphate mines.

Engineering and politics in Jordan 3

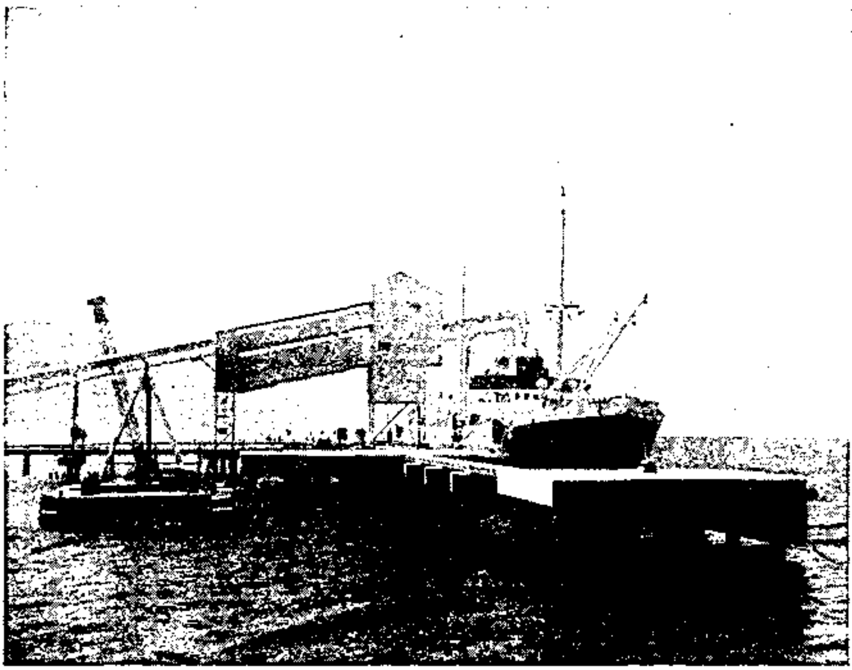


Photo 4. The new phosphate loading berth at Aqaba.

which can now be handled by the combination of the desert road and the new loading plant at Aqaba both of which were financed by Britain (See Photo 4). These should enable the cost of transport and shipping to be drastically reduced. Until recently half the phosphates were exported by road and rail across Syria and the Lebanon, a route at the mercy of the political climate. Opening the Aqaba route will free Jordan from such restrictions but prices to countries north of the Suez Canal will be enhanced by the Canal dues. Commercial success now depends on speeding up extraction and developing the overseas sales organization.

Jordan has all the raw materials for cement and a thriving factory built and run by a West German firm, which has been able to produce 50 per cent of the country's requirements in addition to exporting a certain amount to Saudi Arabia. The factory is now being doubled in size so that Jordan will not be dependent on imports from Syria and can expand its export trade.

Water Supply

Although both Jordan and Israel are desperately short of water for the irrigation of the barren Jordan Valley and Negev respectively, the result of political complications is that two thirds of the flow of the River Jordan is still allowed to run away to waste in the Dead Sea. Several workable schemes have been produced for utilizing this surplus water but all involve co-operation between Jordan and Israel. Under present political conditions it would be quite out of the question for delegates from the two countries even to meet and discuss the problem.

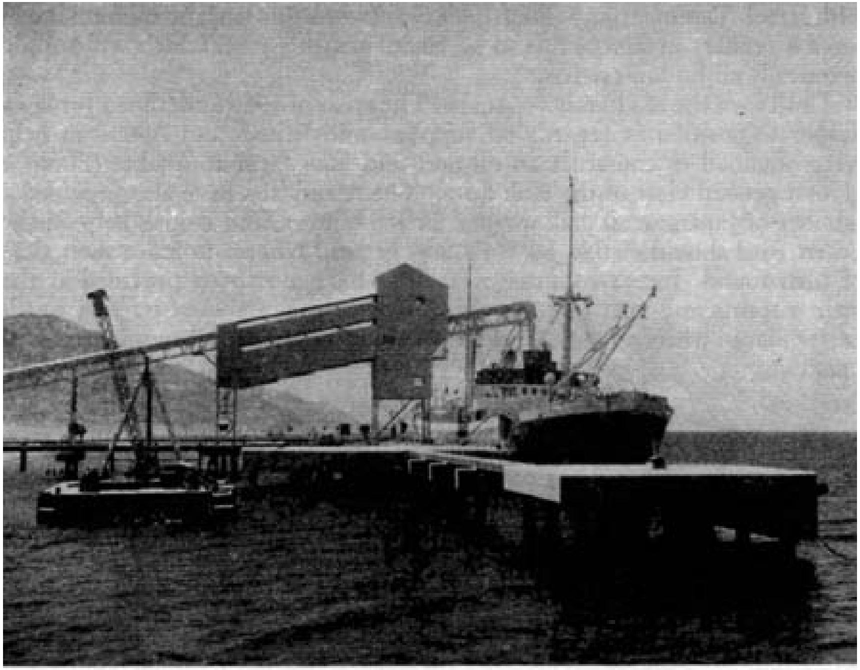
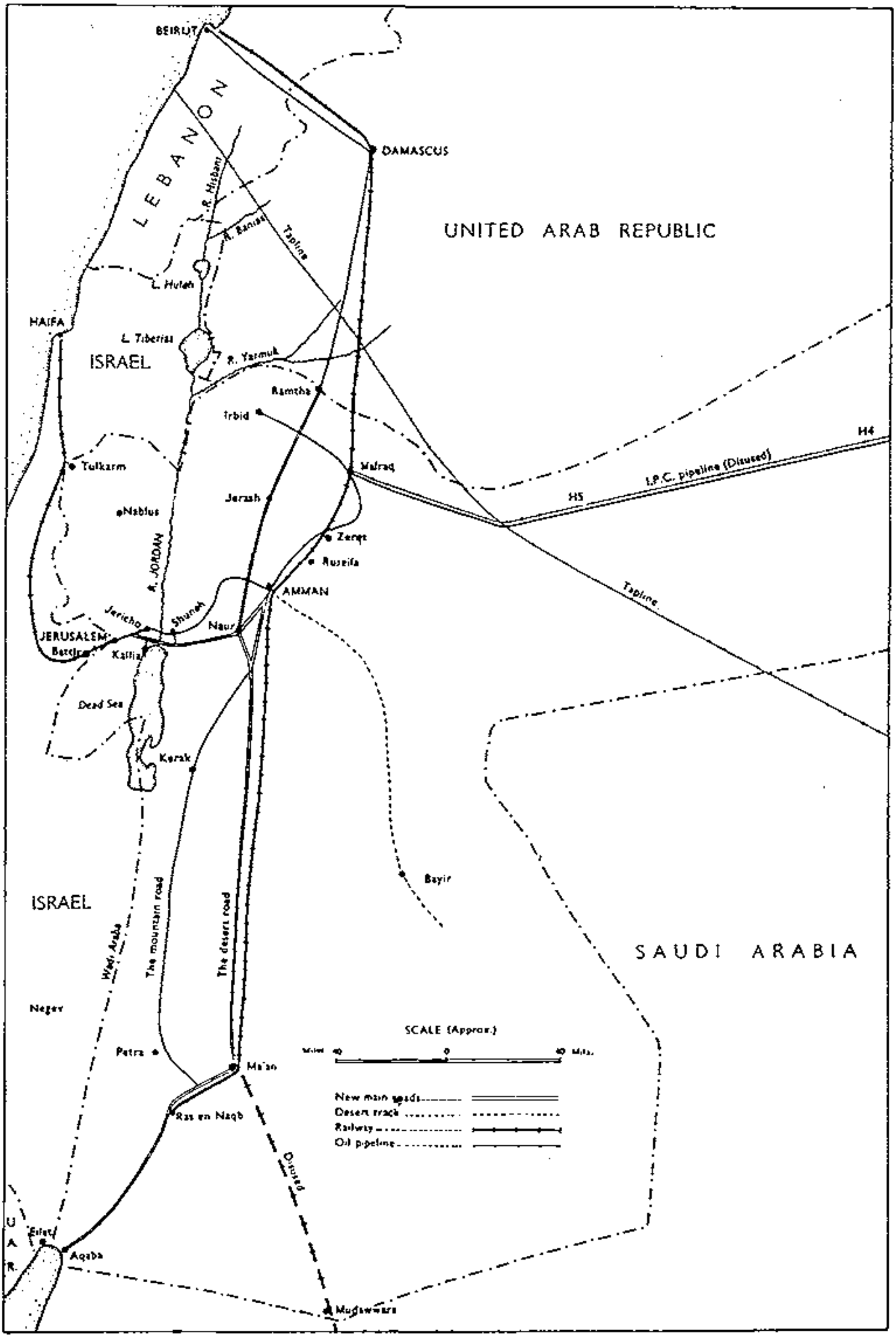


Photo 4. The new phosphate loading berth at Aqaba.

Engineering and politics in Jordan 4

JORDAN

(part diagrammatic)



An unwritten precept of international behaviour does not permit any country to injure another's interests by water appropriation. The geographical facts are that the River Jordan rises in Arab territory, being fed by the waters of the Hisbani, Banias and Yarmuk whose catchment areas are in the hills of Lebanon, Syria and Jordan. The upper reaches of the River Jordan and Lakes Huleh and Tiberias are however under Israeli control. Then for 20 miles the river is itself the frontier before it passes wholly into Jordan on the last 40 miles of its passage to the Dead Sea. Israel is pushing ahead with plans for drawing off water from Lakes Huleh and Tiberias and piping it down to the Negev. Jordan has also embarked on the Eastern Ghor Canal project financed by American loans, which draws off water from the Yarmuk. In the absence of any prospect of a joint solution both countries are thus going ahead with plans of their own, which are admittedly only a second-best expedient.

Defences

The Jordanian frontier with Israel, more correctly the "cease fire line", has never been ratified and represents the approximate position at the time of the final truce in 1949. It is watched over by the Mixed Armistice Commission. This is a body whose chairman is a member of the United Nations Truce Supervisory Organization, but the Jordanian and Israeli delegates have not met officially for several years. However they frequently ring each other up from their offices on opposite sides of Jerusalem's no man's land to carry on the day to day business of returning stray cattle, exchanging daily papers and co-operating over insect control. UN observers in white jeeps rush to the scene of any "incident" and report back to their HQ in the old Government House outside Jerusalem.

The cease fire line runs across villages, roads and railways and cuts off many farms from wells, vineyards and schools. For long stretches it is hardly traceable on the ground, being delineated only by white stones several hundred yds apart. Arab farmers in Israel exchange gossip and cigarettes with Arab farmers in Jordan as they plough adjacent fields. Women from both countries take turns at drawing water from a well exactly on the frontier. Cattle and old women gathering sticks frequently wander over the border and get themselves impounded.

Yet in other places the Royal Jordanian Engineers have constructed minefields, barbed wire defence, pill-boxes and command posts. Not all of these are sited in positions vital to the defence. I have seen one machine gun post prepared ten years ago, which now faces a flourishing orange grove just across the frontier. These defences have been maintained purely for political reasons. Firstly to show the other Arab states that Jordan is "not prepared to yield an inch of the beloved homeland to the common foe" and secondly to reassure the inhabitants of Jordanian villages which have been subjected from time to time to Israeli attacks.

Survey

Survey in Jordan is not just a matter of making maps. A British firm obtained a contract for taking air photographs of most of the country east of the Jordan some years ago but strips cannot be flown on the west bank without photographing bits of Israel and violating her air space at each end of the run. Trigonometrical data was produced under the Palestine Mandate, but was all left behind in Israel when the fighting broke out in 1948. Maps are desperately needed for land revenue, town planning and irrigation purposes, but neither air photographs nor ground control are at present available.

TELECOMMUNICATIONS

The able and enlightened Director of Posts and Telegraphs in Jordan takes the view that international communications must be neutral and above politics. On this basis he is trying to get Amman accepted as the telecommunications centre of the Arab world with consequent financial benefit to Jordan if he succeeds. A combination of political and geographical factors puts Amman in a very strong position as compared with Cairo, Damascus or Baghdad. As it is communications between Cairo and Damascus and between Baghdad and Beirut are routed through Amman and commonsense would dictate that Amman should be selected, but politics may force a different choice.

In spite of the quirks of politics and with the aid of British and American loans Jordan's economic potential is thus being developed intelligently and steadily towards a greater degree of independence. Improved means of transportation by road, rail and air will assist Jordan to exploit her tourist attractions and mineral wealth. Refugee manpower will gradually be absorbed in an expanding economy. Better utilization of available water will lead to increased food production. If the political situation can be kept stable and Western financial support continued, Jordan's future is rosier than would have been thought possible four years ago.

The "Pill-Box Row". The Defensive System of the BEF in France, 1939–1940

By MAJOR-GENERAL R. P. PAKENHAM-WALSH, CB, MC, E-in-C, BEF 1939–40

THE publication of "The Private Papers of Hore-Belisha" by R. J. Minney, serialized recently in a Sunday newspaper, has drawn attention, with considerable correspondence in the Press, to what has become known as "The Pill-Box Row"; in other words Hore-Belisha's criticism of the work on the defences in the sector on the French frontier occupied by the BEF in 1939-1940. The account given in the book, and in some of the correspondence is so inaccurate, and casts such aspersions on the work of the Force and on its Royal Engineers in particular, that it is thought right that members of the Corps should be given the facts as seen at the Headquarters of the E-in-C, quite apart from the technical interest in the subject.

When War was declared on 3 September 1939, little was known as to the future role of the British Expeditionary Force except that a force of two Corps, each of two Divisions, to be followed later, as they were trained and equipped, by an uncertain number of Divisions of the Territorial Army, was to proceed to France where it would come under the orders of the French Supreme Commander. It was also known that the French strategy would be of a defensive nature until such time as their forces and those of her Allies would be strong enough to take the offensive. To this end the French had for seven or eight years been building, to cover their frontier with Germany, a system of permanent defences, known as the Maginot Line, after the Minister of War who was in office at the time. This line consisted of a number of large permanent, mutually supporting works with accommodation, work-shops, etc. running some ninety feet below ground and with concrete and armoured cupolas for weapons and observation posts above ground level.

The "Line" originally extended only along the common frontier with Germany from Switzerland to near Givet but, in 1937, the increased international tension forced the French Government to reconsider their policy and, while General Gamelin, who was now French Chief of the Staff, would have liked to extend the line northwards along the frontiers with Belgium and Luxembourg, it was considered that time might not permit of doing this on the scale of the Maginot works. It was, therefore, decided gradually to extend the line from Givet to the coast in the form of a single line of comparatively small concrete emplacements at about one kilometre intervals with a continuous anti-tank obstacle between them.

While, therefore, the exact role of the BEF was not known it was clear that the creation and manning of a defensive position would be the first task of the Force. Accordingly, shortly before the outbreak of war, the RE 1st Division were instructed to study the construction of concrete defences.

The advanced party of GHQ arrived in the "collecting area", about Le Mans, on 5 September and from 6 to 10 September the DCGS (Major-General P. Neame) and myself as E-in-C visited the French GHQ and toured the existing defences on the frontier between Valenciennes and Armentières, but it was not till 28 September that the BEF was allotted a sector on the frontier between Maulde and Armentières and that it was decided that GHQ should move to the concentration area about Arras two days later.

On 29 September I heard by accident from Movement Control that a force of two RE battalions, each of five Field Companies and a Field Park Company under a CE might be expected in France about the end of October. Neither the General Staff nor my Headquarters had heard anything about this and were distinctly puzzled. But later in the day I received a letter from the Controller of Engineer Services at the War Office, Major-General D. S. Collins, that this force was to build a rear defence line and that its CE, Brigadier A. Minnis, and his DCE, Colonel J. French, a Territorial officer who was a Director of a large firm of Contractors, would arrive on a visit during the next week. The last paragraph of the letter said that the Secretary of State laid great importance on this scheme.

This information, added to that given by Minnis and French on their preliminary visit, indicated that this ("X") force was intended for the building of a line, something on the lines of the Maginot Line, in rear of the BEF sector, Mr Hore-Belisha having been impressed on a visit to France in 1937 with that project initiated by a French Minister for War whose name it perpetuated.

Such a project was completely unrealistic for, even if it could be carried out in the time likely to be available, there would be little use in such a line constructed in the British sector, a matter of about 20 miles, if the French forces on either flank did not build similar defences and there was no indication that they intended to do so. Lord Gort, therefore, decided that X Force should be used to build concrete defences in depth in the British sector, in addition to those built by formations. Further that the work should be organized on mass production lines, not only to increase the speed of construction, but also to facilitate relief of garrisons by avoiding unnecessary variety in design. For such work, as indeed for the original War Office project, X Force was badly designed. What was needed was a mass of skilled and semi-skilled, mostly of concreting trades, labour with a small proportion of skilled men and a quantity of special equipment. "The Private Papers of Hore-Belisha" is inaccurate in stating that the Force consisted of men drawn from industry mostly of the concreting trades; further it implies that the Force would act under the War Office and not under GHQ, an idea, quite unacceptable, and never hinted to Lord Gort, and indeed Hore-Belisha's letter to the latter, quoted in the book, speaks of his sending out the force to Gort. A purely engineer force cannot construct a position without direction from the General Staff.

During the first visit of Minnis and French, though siting decisions could not be complete as formations had not yet taken over their sectors, a general scheme with priorities was worked out with the General Staff and designs for concrete emplacements prepared so that suitable plant and steel shuttering could be ordered. These designs needed careful consideration so that they could be limited to about five types to suit varying conditions and also so that they could take the weapons, principally anti-tank and machine guns, of both British and French armies as it could never be certain of which might have to occupy them when fighting began. Existing French pill-boxes had been designed for their own weapons and would not take British weapons without alteration either to the embrasures or to the mountings of the weapons. This led to an ex-war correspondent, who plunged into the correspondence about the book, stating that the pill-boxes built had such narrow entrances that the legs of our machine-guns had to be sawn off to get them in, he not being aware that the legs of our machine-guns folded up and could be taken through an entrance that a man could negotiate. The French Inspecteur Général du Génie, Général Phillippe, undertook that in future all pill-boxes built by French forces would similarly take the weapons of both armies.

Though the Force as constituted was unsuitable for the job we decided that we must make the best use possible of it, and Minnis and French returned to England to organize the Force and obtain equipment. But, in the meanwhile, the problem of manpower for the execution of engineer work had grown greatly. Many more units were required for work on the base installations, which were scattered widely throughout Normandy, the L of C which was 300 miles long, and for the construction of about fifty airfields both for the Air Component BEF and for the Independent Air Striking Force in the region about Rheims.

There was considerable discussion between the War Office, the BEF and the French Government as to how the necessary labour should be provided. I was delayed in making a visit to the War Office to try to get a decision by a number of visits by VIPs for which my presence was required so that when Mr Hore-Belisha visited the BEF late in November the matter was not settled though as E-in-C I favoured the formation of about sixty companies of two different types, namely General Construction Companies, mostly composed of concreting trades, and Artisan Works Companies of more general building trades. Failing these I was prepared if political and security considerations allowed, to accept, if unwillingly, other solutions such as contractors from England or Anti-Fascist refugees from Italy or Spain.

A Mechanical Equipment Company RE was formed and sent to France for the excavation of anti-tank ditches and many other requirements of the BEF. This was employed under GHQ and machines and their operators were allotted to formations for definite tasks under the technical direction of its own officers.

I and II Corps moved into the line during the first fortnight in October and immediately started laying out and working on the defences. "X" Force started to arrive about the end of that month and, after assembling what plant had arrived and organizing their base for mass production, was allotted certain jobs in the rear parts of Corps areas. None had, therefore, been long in position when Hore-Belisha arrived on a visit on about 20 November. As the visit was to be a short one it had been ascertained in advance that he wanted specially to see the troops and not particularly the work. His programme was arranged accordingly. In the course of his tour he did, however, see a few pill-boxes being constructed by Corps Engineers and "X" Force and excavators working on anti-tank ditches. I was sent for at the end of his visit to talk to him. His first remark was that Minnis and French seemed unhappy. I replied that none of us were very happy about the Force which had been sent out with unsuitable trades and short of plant and transport. Further, we had just been informed that the TA units of "X" Force would be withdrawn when their Divisions were nearly ready to move to France and that the first three would leave in about a month. I explained that after the units and plant had arrived from England there was much preparatory work to be done on approaches and on organizing materials on the site and in the central workshops where reinforcing bars etc. would be cut to length, bent and bundled in sets for despatch to sites, so that work might proceed smoothly and rapidly on mass-production lines on a large number of works. I showed him the five designs for pill-boxes and explained why they had been limited in number.

After this visit I flew to England to discuss at the War Office the provision of labour. French also flew over to arrange for the supply of plant and we arranged to meet in case there were further points to discuss. The question of raising new Companies on the lines I had suggested progressed against the counter-proposals mentioned above, but it was some time later that their formation was approved and French and Appleyard, the CE for airfield construction for the Air Component also an RE TA officer and a contractor in civil life, were authorized to assist in raising them which was done with considerable and rapid success.

On arrival at the War Office I was told by General Collins, CES, that Hore-Belisha had said on his return from France that we had a lot of plans of pill-boxes but could not make up our minds which we wanted. This after my careful explanation to him! During my visit I had two interviews with Hore-Belisha as well as attending at his request a meeting of the Army Council. At both interviews and at the meeting of the Army Council I was accompanied by Collins, and French was also present at the second interview. At the first interview he asked me how pill-box construction was progressing and I told him that most of the preparatory work had been completed and that actual construction was going well and would increase in speed now that preparations were organized. He said that he had been round the line and had seen only two pill-boxes being built. I said that was possible as he had been shown troops not works and that, by Gort's special instructions, great trouble had been taken over camouflage and concealment. I could not give him figures as I had not come prepared to discuss the matter but I knew of a considerable number well in hand. He also said at both interviews that Gamelin had told him that the French were building pill-boxes in three days. We all three laughed at the idea and could only suggest that Gamelin meant that they were building at the rate of one every three days on their front. Later I heard that our CIGS, General Ironside, had been told by Gamelin that what he said was that the French were using a cement which set in three days and that they counted on building a pill-box in eighteen days. At the Army Council meeting, and repeated at our second interview, Hore-Belisha said he had been to the War Cabinet and that the Prime Minister had expressed his anxiety about a report made by the Foreign Secretary, Mr Eden, and representatives of the Dominions, who had recently visited the Front, as to what they considered the weakness of the BEF sector which he himself had noticed and that the Prime Minister took a very serious view of the matter. Hore-Belisha added that the Dominion representatives had gone from our sector to the French and so were able to compare the two. I said that my information was that they had only visited that part of the French front where full Maginot works existed. This was confirmed to me several months later by one of the party who added that their anxiety about the defences referred to all those sectors other than the Maginot Line and not only to those in the BEF sector. I explained to the Council the state of the defences in our area on arrival, our plans for development, and that we were aiming at constructing a minimum of six pill-boxes per kilometre of front, a standard set by Général Billotte, the Commander of the Northern Group of Armies. This would amount to about 240 in all on the front we expected to have occupied by the spring, including the existing French defences, and we hoped, weather permitting, to have a large proportion completed by March. Hore-Belisha then reverted to what he reported the Prime Minister had said and told me to tell Lord Gort. This I promised to do and left the room as that was the only subject in which I was concerned.

On my return to GHQ I gave the message to Lord Gort and at his request obtained from General Collins a confirmation of the terms of the message. This agreed with mine except that he said that Hore-Belisha said as I left the room, and which I probably did not hear, which was true, that the message was not meant to cast aspersions on the C-in-C. I also got an up-to-date report on pill-box construction which showed that, besides the existing French works, some sixty pill-boxes were in hand by formation engineers and by "X" Force. This some six weeks after the arrival of the first British troops in the line.

Gort naturally resented the receipt of such a message sent verbally through a member of his staff.

In the next fortnight there was a stream of visitors. The first was General Ironside, CIGS, apparently on the instructions of the War Cabinet. He spent two days on a very thorough investigation of the position. The following are some of the points made in his report on his return to England:—

He had walked round the front thoroughly and had seen the enormous amount of work that had been done. Over 200 tons of cement was being put in daily by one Division alone. Owing to the low lying nature of the ground on part of the front the digging of trenches was impossible so most of the defences were pill-boxes concealed in copses, hedges and buildings which could not be seen until one was right on top of them. Preparations for demolitions in rear of the front had not been made by the French and had been done since the arrival of the Force. Preparations for inundations had also been made on our right flank and in the centre. A lay-out for a complete buried cable system, to be dug by mechanical diggers, had been made and was progressing at the rate of about half a mile a day. Four diggers were at work and more were coming out. Hundreds of tons of material had been used in artillery positions. For road making 240 tons of metal were used each day. 1350 yds of anti-tank ditch had been completed in the previous week by about fifteen mechanical diggers. It was only just possible to keep pace with essential revetment behind the digging machines.

A few days later H M King George VI arrived on a long arranged visit and I spoke with him on the various projects and especially on the problem of the extra labour required for engineer work. A week later Mr Neville Chamberlain, the Prime Minister, visited the BEF and was shown the work done and in hand. He questioned Gort as to the accuracy of the message I had brought from Hore-Belisha on which, thanks to Collins' confirmation, he was able to assure him.

Immediately after the departure of the Prime Minister I went, on Gort's instructions, to visit Général Condé who was considered to be the French expert on the use of concrete in the defence both tactically and technically. Condé commanded the French 3rd Army in and about the Maginot Line around Metz and I had a long talk with him and visited some of the Maginot works and auxiliary defences. Gort had told me to arrange this visit and then to produce for him a paper on "The Tactical use of Concrete" to enable him to get a common policy throughout the BEF but the visit had to be postponed until after the visits of VIPs.

On 5 January 1940 Hore-Belisha resigned. Minney's book and part of the Press suggest that "many scheming officers" at the Front around Gort who were seeking a means of getting Hore-Belisha out "were pleased when they saw their chance". Such an idea of a plot and ganging up against him is clearly absurd when the facts are studied. He had been welcomed on his visit and the book itself bears witness to the efforts made to show him all he wanted to see, and it was a shock to Gort and all others when, after the visit on which he had expressed satisfaction, Hore-Belisha launched his criticism to the War Cabinet of the alleged lack of energy in creating defences. Thereafter the Prime Minister, having investigated the facts personally and through his military adviser, Ironside, dealt with the matter himself. Nor can it be imagined that the senior formation Commanders who "surrounded

Gort", and who included such men as Dill, Brooke, Alexander and Montgomery, would be party to any ganging up to get rid of the Secretary of State for War.

In spite of these upsets and one of the hardest winters experienced for years, work went steadily on. As General Construction Companies were formed and arrived in France they replaced the TA Field and Field Park Companies originally sent out with "X" Force. Steel shuttering for the standard designs and other plant was received, and production on mass production lines proceeded at ever increasing tempo, so that by May, when the Germans invaded Belgium, over 400 pill-boxes had been completed and many miles of anti-tank ditches excavated and revetted.

It must be remembered that these defences formed only a part of the programme of engineer work being carried out at the time and that careful control had to be kept of the available labour and material. For example, the requirements of the Force in stone aggregate for roads, airfields, pill-boxes etc., amounted at the peak to about fourteen train loads a day, but it was never possible, owing to the congestion on the French railways and the many other requirements of the BEF, newly settling in, to obtain more than about nine. Timber was scarce, hence the importance of steel shuttering for standard designs of pill-boxes.

The book implies that there was jealousy of and discrimination against such Royal Engineer Territorial Officers as French, amongst senior regular RE officers. I personally saw no trace of this and I can only imagine such an idea sprang from the small percentage of officers, to be found in all organizations, who are themselves jealous of those in authority. We in the Corps had all learnt in peace and war to value the work of experienced engineers from civil life. Allotment of materials, labour and equipment was made purely on the priority of the jobs as decided by the General Staff. It was thanks to the co-operation of all concerned that the work was carried out so expeditiously, and in this I would like specially to mention support received from senior RE officers at the War Office led by General Dudley Collins.

In this article I have confined myself to presenting the story of the work on the defences as mentioned in Minney's book though much might be said in addition about airfield construction, tunnelled headquarters, roads and railways, etc. which formed such an important part in the defensive system, and which are described in Volume VIII of the History of the Corps of Royal Engineers.

The Centenary of the Prince Consort's Library, and One Hundred Years of Aldershot

THE history of Aldershot as a military garrison dates from January 1854 when 25,000 acres of waste, uncultivated and uninhabitated heathland were purchased by the War Department for use as a training area. Until then, there had been no permanent camp or garrison in England where large-scale manoeuvres could be held. The area had been surveyed by a party of Royal Engineers during the previous year and plans had been prepared to build a "Camp of Exercise where troops might be tested". Immediately after the purchase of the land an RE yard was established in the area of the present Prince's Gardens and by May sufficient huts had been erected to accommodate the advance party of the first unit to serve at Aldershot—the 94th Regiment, the 2nd Battalion Connaught Rangers. With the outbreak of the Crimean War in March of that year it was decided to incorporate permanent barracks in the plans for the Aldershot Camp of Exercise. Work on these started the following September and by 1859 accommodation had been provided for a Cavalry Brigade at Warburg, Willems and Beaumont Barracks, for an Infantry Brigade at Talavera, Salamama and Badajos Barracks and for a Brigade of Royal Horse Artillery and Field Artillery in Waterloo Barracks. The only permanent buildings on the land acquired in 1854 were the Row Barge Inn, close to the Basingstoke Canal, and the Union Poor House on Hospital Hill. The former was used as an RE Office until it was demolished and the site included in the grounds of the Officers' Club which was built in 1858. The Sappers in Aldershot have, nevertheless, always retained a close riparian association with the Basingstoke Canal in Gibraltar and Malta Barracks built on the site of part of the old RE Jumping Paddock. The Union Poor House became the first Aldershot Military Hospital. It still stands today although it is no longer used as a hospital but houses the District Pay Office.

From the time work on the camp at Aldershot first began the Prince Consort took a lively, personal interest in its construction. He paid several visits to the site and made many suggestions on the lay out of the camp, including the provision of a Royal Pavilion, where the Queen might stay on her visits to her Army at Aldershot. In June 1855, Queen Victoria, accompanied by the Prince Consort, came to Aldershot for the first time and reviewed the troops of the garrison. Thereafter Royal visits became frequent and spectacular parades were held on the Long Valley, on Queen's Parade and on Laffan's Plain. Laffan had been a Deputy Inspector General of Fortifications at the War Office when the Aldershot Camp of Exercise was first planned, and from 1866 to 1872 he was CRE at Aldershot. The plain that bears his name was in those days an undrained, low-lying area, close to the RE Barracks, where in winter it would indeed have been difficult to distinguish, as the famous Sapper song says, "mud from clay". Laffan rose to the rank of Lieut-General and died in 1882 whilst holding the appointment of Governor and Commander-in-Chief of Bermuda. He was at one time a personal friend of Ferdinand de Lesseps and, under instructions from the War Office while CRE at Aldershot, he visited and reported upon the construction of the Suez Canal. Later at de Lesseps' invitation he attended the opening of the Canal in 1869. As a result of this visit there is in the RE Museum, Chatham a report written by de Lesseps on his great engineering project, presented to the Corps by de Lesseps himself. As a result of the 1956 Suez operation there is also in the museum a bust of de Lesseps brought back by the Chief Engineer of the British troops engaged in that operation to save it from the ignominious fate that befell the famous statue of de Lesseps which used to stand at the entrance to the Canal.

From the end of the Crimean War until the South African War the "Division at Aldershot" settled down to a regular training routine and more permanent buildings were erected to meet the soldiers' material and spiritual needs. At the outbreak of the South African War over 60,000 men were mobilized at Aldershot, equipped and sent overseas within a few months. The Old Contemptibles also mobilized at Aldershot in 1914 and, with the departure of the Regular and Territorial Armies overseas, Aldershot became the training ground for many of Kitchener's New Army Divisions and throughout the war many thousands of men were trained there for every theatre of operations. Between the two world wars, Aldershot Command, which included a Cavalry Brigade and the 1st and 2nd Divisions, resumed its traditional training role for the Regular and Territorial Armies and for the Officer Training Corps and gave birth to the annual Aldershot Horse Show and the famous annual Aldershot Tattoo, made possible by the lights of the Searchlight Battalion RE, then stationed at Blackdown. The 1939 Tattoo attracted over half a million spectators to the Rushmore Arena. Within two months the soldiers who had taken part in that last Tattoo departed for France with the British Expeditionary Force and Aldershot became once again a great wartime training area, especially for the 1st Canadian Army. It became also one of the concentration areas for the 1944 Invasion of Normandy. Overseas manpower commitments prevented Aldershot from returning after the 1939/45 War to its position as the major peace-time home garrison for Divisions of the Army, and it became instead a training centre for National Service Officers and Regular and National Service recruits for many Corps, including the Sappers. Aldershot has also become the home station of the Parachute Regiment and the Headquarters of the Airborne Forces, an Arm undreamed of by the Prince Consort despite his prophetic vision.

The Military Centenary of Aldershot was celebrated in April 1954 with a ceremonial parade in which over 3,000 officers and men marched past the Mayor and the General-Officer-Commanding Aldershot District, Major-General Campbell, now Major-General Sir Douglas Campbell, this year's Representative Colonel Commandant RE and President of the Institution of Royal Engineers.

So much for the outline history of Aldershot and its Sapper connexions; now to hark back to the Prince Consort to whom the well being and education of the Army officer was always dear. In June 1859 he offered to the Officers of the Camp at Aldershot a collection of a thousand books and a library to be built at his own expense to house them. He entrusted the design of the library to Captain Francis Fowke RE. Work started in September 1859 and it was completed exactly one year later.

Captain Francis Fowke was an outstanding Sapper officer. He was commissioned into the Corps in 1842 and very soon demonstrated his inventive genius and brilliance as an architect. He designed a type of military folding boat that, although not brought into service in the British Army at the time, was accepted by the Americans. He devoted much thought to the adaption of rifling to heavy guns and in this respect he was a precursor of both Armstrong and Whitworth. It was, however, as an architect that he was pre-eminent. His work in the British Section of the Paris Exhibition of 1854 gained him international fame. Later he designed the interior of the Dublin National Gallery and the Museum of Science and Art in Edinburgh. He was also employed on the design of structures for the 1862 International Exhibition. His best known architectural works are, however, to be found in the Kensington Museums and the Albert Hall. He died while still young in December 1865. His memory is perpetuated in the Corps by the Fowke Medal awarded each year by the Institution of Royal Engineers. It is the oldest of the Institution prizes and it was established a year after Fowke's death. The first medals were struck at the Royal Mint. They were originally awarded as an "architectural prize". There are now two types of medals; two silver medals are awarded annually to young officers who have specially distinguished themselves on their Courses at the Civil Engineering School of the SME, and a bronze medal is awarded annually to the NCO or Sapper who has similarly distinguished himself.

The opening of the Prince Consort's Library was announced to the Officers of the Army and Militia serving at Aldershot in a General Order issued on 14 September 1860 by the Commander-in-Chief which entrusted "to their special care the preservation of a gift so generously bestowed"—Unhappily the Corps, to whom had been given the honour of providing the first Librarian, produced a certain Corporal Weston who, a few days before the opening of the Library, was discovered to be a deserter from the Inniskilling Dragoons. He had to be replaced at short notice and the Sappers were not asked to find the substitute.

An exhibition to celebrate the centenary of the Library was opened by Lieut-General Sir Richard Goodbody, Adjutant General to the Forces, on 24 September 1960 and to mark the occasion he handed over "to the special care" of Major-General D. S. S. O'Connor, General-Officer-Commanding Aldershot District, three watercolours of the Camp of Exercise at Aldershot, painted about 1856, graciously presented by Her Majesty the Queen. The exhibition included a Book display and a Museum display, the latter containing exhibits from Regiments and Corps that have had a close connexion with Aldershot. The Sapper connexion of course spans the full hundred years and the items displayed illustrated some of the activities of the Corps at Aldershot during that period. They included models, photographs and drawings of the kites, balloons and biplanes used by the Balloon Sections and Air Battalions RE; models and photographs of equipment used by the Telegraph Battalions RE, Road Steam Transport (manned by the Sappers during the South African War) and Searchlight Battalions RE; photographs of field work training and mounted duties training at Aldershot; types of uniform worn by the Royal Engineers during the last hundred years; photographs and papers dealing with Laffan and Fowke, including a bust of the latter and examples of the Fowke medals, and a Sapper produced map of "Aldershot and its environs" dated 1860. The RE Mess Aldershot and the recently formed

Aldershot Branch of the RE Museum loaned the South African War silver centrepiece, the Skipwith Horse, the Victoria Cross and the other medals of Corporal W. J. Lendrin, Royal Sappers and Miners, the first other rank Sapper VC awarded for an act of gallantry in the Crimean War, and the baton, decorations and medals of Field Marshal Sir Lintorn Simmons, one-time Colonel Commandant RE.

Future Engineer Organization

By MAJOR M. J. W. WRIGHT, RE

(*Author's Note.* The author has been serving in Canada for the last three years. This article, while not representing Canadian Army Policy, is based on ideas put forward at RCE exercises attended by the author.)

THE AIM

IN an article, "The Infantry Brigade Group Field Squadron", published in the *RE Journal* for June 1960, the author outlined ways in which the present field squadron could be re-organized to meet the needs of a nuclear war in the next few years.

Looking further ahead, say to the period 1965–70, it is probable that a complete re-organization of Brigade and Divisional Engineer units will be needed; the aim of this article is to not suggest a new organization, but to suggest a method of approach to arrive at one.

THE PROBLEM

Admittedly, this is no easy problem. We will be dealing with a new tactical concept with which we are not yet familiar, we know very little about the organization and equipment of our potential enemies in this period, and lastly, we are not even certain of the organization and equipment that our own and allied forces will use.

One wonders indeed, with so many uncertainties, whether the task is worth attempting. It is considered that a reasonable solution can only be obtained if:—

The problem is tackled in a logical fashion;

The uncertainties are evened out by having as many solutions as possible produced and taking the mean of the many.

THE APPROACH

Whether we are trying to decide on the engineer support needed by a brigade or a division, or indeed any formation, the same logical process should be followed. This process falls into five steps, as follows:—

The Basic Brick. What is the ideal size for the section of the future. What equipment and transport does it need.

Endurance. How many hours can the section work each day.

The Size of the task. How many of these sections are needed in the formation.

Command and Control. How should the required number of sections be grouped to provide the support needed.

Additional Support. What additional equipment, transport or manpower is needed within the unit to support the section.

The Basic Brick

The size of the field section varies very considerably at present in different armies. Even Allied and Commonwealth armies which to a great extent use the same or similar equipment have different sized sections.

What is needed is a detailed study of the various engineer tasks likely in the period 1965–70, and the equipment which will be in service by then, to determine how many men, how many NCOs and what organic transport and equipment is needed by the section.

It is obvious that the size of the section is very much dictated by the equipment available. This is in particular true with the type of vehicle which will carry the section and be organic to it.

However, since the average lead time for most hardware is eight to ten years, it should be reasonably clear at this time what equipment will be available in the time frame under study, and so there should be little difficulty in fitting the manpower to the equipment.

This part of the study may well disclose that certain tasks are constant, specialized, and do not fit the section needed for most tasks. Such tasks are lighting Brigade HQ, running water points and assisting Brigade HQ to dig in. It is suggested that such tasks are best undertaken by a small number of specialist sections; it may be possible, for example, to form a small section permanently detached to main Brigade HQ, to run their lights, dig them in and run a forward water point. A further similar section might be needed by rear Brigade HQ, leaving the greater part of the unit manpower available to be organized into the basic bricks.

Endurance of the Basic Brick

Having decided on the size of the section, the next step is to decide how many hours of engineer work it is reasonable to expect the section to undertake in each 24-hour period.

An analysis of what a section does in each 24-hour period will show that time is spent eating, sleeping, digging protection on the task and in the harbour area, guard duty and moving to and from tasks. The balance of the 24 hours is available for engineer work. If more work is needed, then time spent on other activities must be reduced. It is possible to reduce movement time by sound planning, thereby eliminating unnecessary moves, and by using APCs and helicopters to move between tasks. It may be possible to reduce the time spent on digging in by using power tools of the "Cobra" type. It is difficult to reduce the time spent on guard duty, unless harbour areas or work sites are within the protective areas of other units. This leaves eating and sleeping time, which cannot be reduced below a minimum. We all know of cases where troops have worked for long periods without proper meals or rest; this is certainly acceptable, and even essential under certain circumstances, but it is not a sound assumption to make when planning a future organization.

What is required is a really sound study of how much of the 24 hours all these various activities will take up, and hence, how much is left for engineer work. This study must be sufficiently convincing to show other arms why sappers only work for eight or ten hours each day, or whatever figure the study recommends. One often hears the infantry complaining that their soldiers work a 24-hour day; this study will probably show that what in fact the infantry soldier does is in a large part also done by the Sapper in addition to his engineer task.

The Size of the Task

Having decided on the size of the section, and how many hours it can work each day, the next step is to decide the average number of section days work there will be in the formation per day, and hence how many sections are needed.

This will best be done by setting two, or better still, three, engineer exercises, each based on a different phase of war. Very rigid assumptions would be issued with the exercise papers, and the exercises would be held by each of the five UK Chief Engineers, the main overseas Chief Engineers, HQSME and possibly the war games section of AORG, as a winter study, lasting three or four days. The results of these exercises, carried out by ten or so different groups of officers scattered around the world would produce ten or so different solutions to the number of sections needed.

By averaging these solutions, the undue emphasis of one facet of the problem produced by the experience or bias of one group of officers, would be evened out. This investigation should show convincingly just what effect the new concept will have on the overall size of the engineer task. One often hears such statements as "the advent of nuclear warfare has vastly increased the engineer task". This may be so, but what people want to know is why and how much.

Command and Control

We will now know how many sections we need, and how big they should be. The next problem is to decide how to group these sections into troops.

For any given number of sections, there are endless permutations and combinations; even at the moment, in the Canadian Army, with twelve sections in the field squadron, there is continual discussion on whether there should be three Troops of four Sections or four Troops of three Sections. What is needed is a detailed study to show how the total number of section day's work is divided between battle Group tasks and Brigade tasks; at Divisional level, the study should consider Brigade tasks and Division tasks.

This study would show that each battle Group could usefully employ a small number of Sections on a permanent basis, and a larger number on a temporary basis for particular tasks from time to time. Once the minimum number of Sections needed in each battle Group is known, it will be a simple matter to arrange the sections into the required number of troops.

Additional Support

All that remains now is to decide what equipment cannot be justified within the Section, but will be needed frequently and so should be held at Troop level; it is likewise necessary to decide what must be held at Squadron, Regimental and Group level. Support may either be equipment or manpower, and in either case, the problems of the command and control of the additional support require solution. When considering the problems of how additional support will be commanded, particularly when an additional Squadron is placed under command of a Brigade, or an additional Regiment is placed under command of a Division, a detailed study will be required of the HQ organization.

One often hears it stated that a Squadron commander cannot be a planner and a doer, and that he cannot properly command his own Squadron, advise the Brigade commander and plan future engineer tasks. If this is true, then to place an additional Squadron under his command might prove to be the straw that breaks the camel's back.

It is considered, therefore, that a study should be made of HQ organizations and procedures so that future Engineer Commanders at all levels have the resources available to command their own units and any additional units that may be placed under their command for short periods.

Infantry Pioneers

No mention has yet been made of Infantry Pioneers. It is considered that with the integrated battle Groups of the future, each with their own organic troop HQ and a basic minimum number of sections, there is no need to have both engineers and pioneers within the battle group. In the Australian Army, the battalion pioneer platoons were at one time manned completely by RAE personnel, and it was noteworthy that in Korea, where two RAR battalions were operating with other Commonwealth battalions, the RAR battalions required less engineer support than battalions with infantry pioneers.

It is considered, therefore, that when deciding the size of the Sections and how many sections are needed, it should be assumed that no Infantry Pioneer Platoon is available. On this basis, the study may prove that engineers require a slightly larger slice of the available manpower.

Conclusion

It is believed that only if a study is undertaken on the lines suggested can a sound future organization be evolved.

It is emphasized that the exercises by ten or so groups of Officers will be an essential part of the study because with so many uncertainties only if the work is carried out by a number of separated groups can the personal whims and bias be evened out. This in particular applies to stage three—deciding on the number of Sections needed, but it does apply to stage one and two and, to a lesser extent, to stage four and five.

We Sappers have a reputation in the Army for clear and logical thought. It is up to us to maintain this reputation by presenting a clear and logical solution to the problems of our future battlefield organization. Any solutions full of cliches unsupported by facts will carry little weight with the rest of the Army.

Olden Time

By Major D. M. R. Esson, BSc, AMICE, RE (Retd)

It may interest Sapper officers in general, and amuse the mathematically agile in particular to be reminded of the methods employed to determine longitude and time before the days of wireless telegraphy, particularly as these are not now described in works devoted to astronomical surveying and navigation. Although chronometers had reached a high degree of technical excellence, their rates differed once their habitat changed: this made the determination of longitude inland doubtful, and even the position of a sailing ship at the end of a long voyage out of sight of land was dubious.

When the Royal Observatory at the Cape of Good Hope was established shortly after the Napoleonic Wars, it was necessary to determine its longitude with the greatest possible accuracy. Accordingly a sailing ship took a series of chronometers from Greenwich to the Cape and back again, signalling the time by chronometer to both observatories. The two Greenwich readings gave both the error and the rate, and accordingly the longitude of the Cape was determined.

This method was perfectly good for determining the longitude of such an important point as the Cape of Good Hope, but it did not help a sailing ship captain to check his chronometer in the middle of the Pacific, nor did it enable the weary traveller in Central Africa to fix his position. In fact the latter, owing to the changing and unknown rate of his chronometer due to its carriage over different types of ground, was in a more dubious position than the former: he could determine his local time, his latitude and azimuth easily enough, but to fix his longitude was not so easy.

There were four main methods of determining longitude absolutely, that is to say, determining Greenwich time independently of one's position on the Earth's surface. They were: the eclipses of Jupiter's satellites, the culmination of the Moon and an adjacent star, lunar occultations and lunar distances.

The configuration of the four greater moons of Jupiter are given in the Astronomical Ephemeris for every day of the year with the exception of any period when the planet is invisible due to its proximity to the Sun. These are now given with the times of eclipses, transits and shadows to the nearest minute, but in nautical almanacs prior to 1907 some of these were given to the nearest second. If the time of eclipse or transit of such a satellite were observed in the field, then Greenwich time would be known immediately. This method, however, required a powerful telescope, something of the order of forty magnifications and at least a 3-in object glass, and considerable skill in observation. The clarity of the atmosphere and the rigidity of the telescope stand affected its utility, so that this method was not recommended.

The remaining three methods all depended upon the fact that the Moon retreats across the heavens at about 13½ deg per day. If, therefore, the Moon's right ascension can be determined at any instant of local time, then by interpolation in the Astronomical Epheremis the appropriate Greenwich time may be determined, and hence the longitude can be evaluated. The celestial co-ordinates of the Moon are given in the Ephemeris for every hour, and used to be given in the old nautical almanacs to the same argument.

If a telescope is set up in the plane of the meridian and the local time of transit of a star whose right ascension is known is observed, and shortly afterwards the local time of transit of the Moon is observed, then the right ascension of the Moon may be computed, and hence by inverse interpolation in the Ephemeris the Greenwich time and the longitude obtained. This was regarded as the land surveyor's best method, but it was not so satisfactory at sea owing to the difficulties of observing the horizon at night and of timing transits with the sextant.

The observation of the occultations of stars by the Moon was another method. If the local time of immersion and emersion of an occulted star is observed, then at the mean of these two times the right ascension of the Moon and the star are obviously the same. Due to the proximity of the Moon this is only strictly true on the Meridian but at high altitudes the resultant error will be very small. This method has the great advantage that no correction is necessary for instrumental errors, but again a powerful telescope is necessary to obtain the best results, particularly on the bright limb of the moon. The necessary elements for these occultations used to be published in the Nautical Almanac until 1959, but these have not been continued in the Astronomical Ephemeris. Details of occultations observable in Great Britain, South Africa, Australia and New Zealand are, however, published in the *Handbook of the British Astronomical Association* annually, and details of any other particular occultation may be obtained from the *Nautical Almanac* office, or from any national observatory.

Finally there was the method of lunar distances. This was regarded by most marine navigators as the best of all. If the angular distance between the Moon and the Sun or a star were measured, then the time of observation could be computed. The procedure adopted was to measure simultaneously the altitudes of the Moon and the Sun or star and the angular distance between them. By choosing a star at a distance of about a right angle from the Moon a good "fix" could be obtained from a single set of observations; and, in fact, the lunar distances used to be tabulated for suitable stars at three hourly intervals in the *Nautical Almanac* until 1907. It was necessary to "clear the lunar distance", that is to correct the distance as measured by the sextant for the Moon's semi-diameter, parallax, refraction and its altitude. Due to the proximity of the Moon to the Earth, the position of the observer on the Earth was important, thus it was essential to eliminate the errors due to all these effects. Once the reduced distance was known, the table of Lunar Distances was entered and the Greenwich time determined. But even here the irregularities of the Moon's motion made it necessary to use proportional logarithms for the inverse interpolation. Once, however, the time had been determined, the two altitudes gave position lines, and the chronometer error was known. Where only a single observer with his recorder had to do all the angular measurements, one writer recommended the following procedure. First, determine one's latitude; then after recording the air temperature and adjusting the horizon glass of the sextant and determining its index error, observe three altitudes of a time star east, and the same again west; then three altitudes of the Moon, five lunar distances to a star east of the Moon, five more for a star west, and three more altitudes of the Moon; and finally repeat the six altitudes for time.

Although surveyors and navigators thought well of these methods, and for the resources at their disposal, the results could not be called unsatisfactory, we could hardly accept them today. During a survey in British Columbia in 1910, longitude was determined by lunar occultations and by lunar distances, showing a difference of seven seconds of time. Today we should expect an accuracy of a fifth of a second of time with good instruments and wireless reception of time signals.

These, then, were the methods by which our forefathers navigated the globe and commenced to survey it. Although now they are only of historical interest, they pin-point the necessity of large sextants of those days, and show also the ingenuity of astronomers in providing sailors with non-mechanical clocks.

REFERENCES

1. Surveying by J. Whitelaw, jun. Crosby, Lockwood & Son, 2nd edition, 1906, pp. 383–4.

2. The Bear Creek Hydrographic Survey, British Columbia by F. R. Johnson, MICE, Min. Proc. ICE, vol clxxxviii (1911–12), pp. 371–9.

Memoirs

BRIGADIER RAWDON BRIGGS CBE, DSO, MC, DL

BRIGADIER RAWDON BRIGGS died on 2 September last at the age of 68. He was the son of H. E. Briggs Esq. of Birstwith Hall, Yorkshire and was educated at Bedford School and Leeds University. He was commissioned into the Corps on 17 November 1914, at the age of 22, and served throughout the 1914/18 War on the Western Front with 75 Field Company of the Guards Division being promoted Lieutenant in July 1915 and temporary Major in June 1917. In 1916 he was awarded the MC and 1918 the DSO. He was also mentioned in dispatches.

After the war he held a staff appointment in Headquarters Dublin District before taking his Supplementary Course at Chatham. In 1925 he was made Adjutant RE Troops Aldershot, a much coveted appointment in those days when so many Sapper Field Units were concentrated there.

In 1928 Briggs was posted to India to command 15 Field Company of the Burma Sappers and Miners, then serving a tour of duty on the North West Frontier, at Razmak. In the following year, however, the Company returned to Burma and Briggs, as officiating Commandant, had the unenviable task of disbanding the Corps of Burma Sappers and Miners at Mandalay, then of little more than Company strength. After the disbandment he continued to serve in Works appointments in Burma, mostly at Maymyo, until coming to England on leave in April 1932. On returning after his leave he completed his overseas tour of duty in another Works appointment under the CRE Rawalpindi.

BRIGADIER R BRIGGS CBE DSO MC DL

In April 1933 he was posted to command the RE Mounted Depot at Aldershot and, although by that time "mechanization" was fast arriving and the days of the horse in the Army were numbered, the RE Mounted Depot under "Briggie's" able and enthusiastic command won the Aldershot Command Challenge Cup for Mounted Units and the Team Jumping for NCOs and the Bronze Medal for NCOs' Jumping at the Royal Tournament, besides gaining many individual successes at Horse Shows, including the great Dublin Horse Show itself. Briggs was himself a keen man to hounds and always most helpful to young subalterns taking up fox hunting for the first time and having their first exciting taste of Point-to-Point steeplechasing. He was a pioneer in the use of a horse box trailer to carry his horses to the Meet and to race meetings, and many were his cunning devices to persuade one of his reluctant hunters to enter such a new-fangled contraption. He rode his great bay charger "Binjimin" in the Heavy Weight Race at the RE Aldershot Point-to-Point Meetings in 1934, 1935 and 1936. On the first occasion he won the George Master Horn but at the next two Meetings age began to tell and the gallant Binjimin ran unplaced. He was later, however, to excel as a show jumper.

In June 1937, although he had no previous major road work experience, nor any local knowledge of the Middle East, Briggs accepted an invitation to prepare an estimate for the cost of building in two years an all-weather road on the section of the Haifa—Baghdad route from the River Jordan to the Transjordan-Iraq Frontier, the work to be carried out by direct labour as an Agency Service for the Colonial Office. From 1923 two ex-Servicemen, the Australian brothers Nairn had operated a motor convoy service from Baghdad by way of Rutbah Wells through Syria to Damascus using the old caravan route. At times however the desert became a sea of mud and stoppages of over a week were not uncommon and each journey was somewhat of an adventure. In 1932 the Iraq Petroleum Company had constructed a pipe line to carry oil from their fields at Kirkuk to Haifa and had laid a duplicate line to Tripoli in Syria. The Haifa pipe line followed the most direct route through what was then British Mandated Territory from Rutbah to Haifa irrespective of grade or terrain; alongside this pipeline a track had been built and deep wells sunk by the Company. These were the only land crossings of the great waterless desert and the formidable Lava Belt one of the most desolate and forbidding areas on the face of the earth. The new road planned had, therefore, both great commercial and strategic importance. The estimate was prepared and Briggs was put in charge of the project, a vast engineering task on which a large amount of all types of mechanical equipment was used for the first time in the Middle East. The project also involved a high degree of administrative organization since labour had to be recruited, paid, fed, accommodated, cared for when sick and disciplined at times, the machinery and transport vehicles had to be kept serviced, water had to be produced in the desert, telephone communications had to be installed and an organization set up for the supply, movement and safe custody from pilferage of stores, spare parts and materials. Temperatures varied from blistering heat to 15 degrees of frost at times by night, and during the construction there was a freak and unprecedented rain storm when 13 inches of rain fell in 48 hours. The road was, nevertheless, completed within the specified period and its wartime strategic importance a few years later was incalculable.

Briggs was back in England in time to become CRE 2 Division in the British Expeditionary Force in France in the winter of 1939–40, and he remained with the Division until after the evacuation from Dunkirk. In June 1940 he was promoted Colonel and succeeded Colonel E. E. B. Mackintosh as the Commandant, the School of Military Engineering at Chatham. In addition to his duties as Commandant he was also in command of Chatham Sub-Area with operational responsibilities, and in command of a mixed Brigade composed of a Royal Naval Battalion, a Battalion of Royal Marines, two equivalent Battalions of Sappers and a Group of Local Defence Volunteers (later known as the Home Guard). When the Battle of Britain started Chatham, as a Naval Base and dockyard town, was frequently attacked from the air, indeed Briggs reported that for some months the area was almost as much subject to air raid warnings Red as to All Clear. About 100 bombs fell in the barrack area. One hit the Survey School, another burst in a barrack block basement causing heavy casualties, another wrecked a block of single officers' quarters near the Headquarter Mess and one damaged the Commandant's House. Under such conditions it was almost impossible for the SME to carry out its proper training function and in November 1940 the School set up its temporary home at Ripon. Briggs, however, did not accompany the SME to Yorkshire but was promoted to become V Corps Chief Engineer.

With the fall of France and the partial closing of the Mediterranean, West Africa had assumed great strategic importance for the Navy, Army and Air Force. Troops in the West African Colonies were reinforced as a safeguard against possible French action. Internal communications had to be improved and later an overland air route, reinforced by another employing rail, river and road transport, developed across the Continent to Khartoum and thence along the Nile to Egypt along which all kinds of much needed stores were dispatched to our hard pressed forces in the Middle East. At first there was a wild inter-Service scramble for manpower and local and imported resources of all kind. To remedy this a Director of Works Services was established in early 1942 and Briggs was given the appointment with authority to co-ordinate the engineer activities and resources of the three fighting Services and of the Civil Government within a general directive as to priorities laid down by the Heads of Services Committee in West Africa. He was empowered to make decisions subject to the right of appeal by any of the Services to the Heads of Services Committee. No appeal was, however, ever made during the two vital years Briggs held this most exacting appointment, due to his good sense, scrupulous fairness, tact and unfailing good humour.

Later Briggs served in North West Europe from 1944 until his retirement on 22 December 1945 when he was Deputy Chief Engineer to the Engineer Division of SHAEF. For his war services he was awarded the CBE in 1945, the American Legion of Merit, the French Legion of Honour and Croix de Guerre and the Russian Order of the Red Banner.

After his retirement he became Regional Director, Eastern Region, in the Ministry of Works and he held this appointment for many years. He was also most active in local affairs. He was for several years Chairman of the County of Cambridge and Isle of Ely Territorial and Auxiliary Forces Association and continued to give most valuable assistance to that Association after his tour as Chairman was over. He became a Member of the Cambridgeshire County Council and he was elected Deputy Lieutenant of the County.

On 12 September 1923 he married Esther, second daughter of J. T. Keily of Carrickmines, Co Dublin who survives him with two daughters and to them our most sincere sympathies are extended. J.L.

BRIGADIER A. G. WYATT, CBE

"Jessy" Wyatt was a singularly charming character and his death, aged 59, will be deeply regretted by many friends in the Corps and in the RAF. He was a man of bonhomie in its best sense—friendly, warm-hearted and hospitable. His acts of generosity were many but, like his pictures (for he was a competent artist), they were never exhibited.

Arthur Geoffrey Wyatt, son of the late Geoffrey Wyatt Esq, was born on 2 October 1900. He was educated at Sherborne and from there he went to "The Shop" just as the 1914–18 War was ending. He was commissioned on 16 July 1920 and after a short spell at Aldershot he went to Chatham to join No 4 JO Batch. Here Jessy (origin obscure but probably a childhood corruption of Geoffrey) soon endeared himself with the Batch. He had a tremendous sense of fun and he was an incurable optimist.

Most of his early service was spent in India. In 1924 he had joined the Royal Bombay Sappers and Miners and during the following five years he served with units of that Corps in Kirkee, Quetta, Aden and Fort Sandeman.

In 1931–34 he served in Works appointments in Lahore, Peshawar, Nowshera and Risalpur and in the Mohmand operations in 1934, for which he was mentioned in dispatches. It was whilst serving at Risalpur, mainly an RAF station, that he made contacts and friendships that were to have a considerable effect on his later career. In 1933 he had been chosen for special duty with the RAF, India, and in the following year he went to Army Headquarters at Simla as Engineer Staff Officer to the Director of Civil Aviation—an appointment which he held until 1938, when he returned to England.

At the outbreak of war in 1939, Major Wyatt (he had been promoted the previous year) was commanding 6 Field Park Company at Aldershot. He took the unit to France in 1939–40 and was mentioned in dispatches. Soon after his return to England he was picked out for duty in connexion with airfield construction. At that time very few Sapper officers had had any experience in this field which, before the war, had been the responsibility of the Air Ministry Works Branch. The operational construction of airfields was then a new conception, and the Airfield Construction Group RE was being evolved to meet it. Here Wyatt's experience in India and his long and friendly association with the RAF were invaluable. He wrote an interesting account of how the system was evolved in an article, "Airfield Construction for War", in this Journal for March 1950.

With the temporary rank of Colonel, Wyatt went to North Africa as Deputy Chief Engineer (Airfields) First Army and held the same post on the staff of Chief Engineer 15 Army Group in the invasions of Sicily and Italy. Early in 1944 he went to SEAC as Deputy E-in-C (Air) with the temporary rank of Brigadier and continued in this appointment until the end of the war. He was awarded the CBE in 1943 and the US Legion of Merit in 1944. On return to England he was CRE London District for a time and later commanded 24 Engineer Group (TA). He was promoted Substantive Colonel in 1948 and retired with the honorary rank of Brigadier in 1950.

In 1940 he had married Joan Lindsay Eddis and after his retirement they lived very happily with their two boys at Beaconsfield. After leaving the service he was Registrar of the Faraday House Electrical Engineering College in London until his death, from a stroke, on 26 July 1960.

J.M.L.

COLONEL A. G. B. HUME

WITH the death at Terrington St Clement, Norfolk of Colonel Hume at the age of 93 years on 23 April 1960 the Corps lost yet another link with the early days of military flying.

Arthur Henry Bliss Hume was born in Colombo on 19 February 1868. He was educated at Haileybury and the Shop and he was commissioned into the Corps on 17 February 1888. Immediately after his Chatham Courses he was sent to the Balloon Section on its formation in 1890. Experiments had been carried out with captive balloons in the army since 1878 and balloons had been used in the Bechuanaland Expedition of 1884 and in the Sudan Campaign of 1885 during which great improvements had been made in the supply of gas in the field and in the tactical use of these new instruments of war. No establishment for Balloon Sections was, however, authorized until 1890 when the Experimental Balloon School and Factory were moved from Chatham to Aldershot and Sapper manned balloons became the first officially recognized Air Arm of the British Army. It was to this unit that Hume was sent as a young subaltern and he served with it during its first four formative years.

In 1894 Hume was posted for the first time to India where he was to soldier for a large part of his career. From 1894 until 1896 he was employed with the Military Works Department and from 1897 to 1900 with the Survey of India mostly in the forests of the Madras Presidency.

In June 1900 he returned home on leave but he was almost at once posted to the 4th Balloon Section at Aldershot and in August of that year he sailed with the unit to join the China Expeditionary Force under Major and Brevet Lieutenant Colonel J. R. L. Macdonald RE. On arrival in North China Captain Hume took over command of the Section. The Balloon Section was intended for service with the British Contingent of the International Force sent to Pekin to protect foreign interests menaced by the Boxer rebellion. The Section arrived after most of the fighting was over but balloon ascents were made and the British equipment, due to recent experience in the South African War, surpassed that of the other nations of the International Force which included troops from Great Britain, Germany, Austria, France, Italy, Russia, Japan and the United States. Today it seems almost inconceivable that just sixty years ago an International Force should be composed of soldiers from such Nations and that a junior Sapper Captain should be in command of the most advanced "air component" of this International Force.

In 1901 Hume went with six British NCOs and Sappers of his Balloon Section and some of its equipment and field gas factory to Rawalpindi to establish the nucleus of the Bengal Sappers and Miners Experimental Balloon Section—the first to be formed in India. After he had trained Captain W. A. Stokes RE in his duties Hume left the Experimental Balloon Section and returned to the Survey of India where he stayed until 1906, being employed on a forest survey in Burma and a topographical survey of the Central Provinees, India.

Major Hume returned to England in 1907 and served as Division Officer at Gosport and Hillsea before returning to India in December 1910 where he was once again employed with the Military Works Department at Dehra Dun and Allahabad. He was promoted Lieutenant Colonel in March 1915 and took part in the Black Mountain Expedition in the North West Frontier

Colonel AGB Hume

Correspondence

126 Hughenden Road,
Marshalswick,
St Albans, Herts.
19 October 1960.

The Editor,
The Royal Engineer,

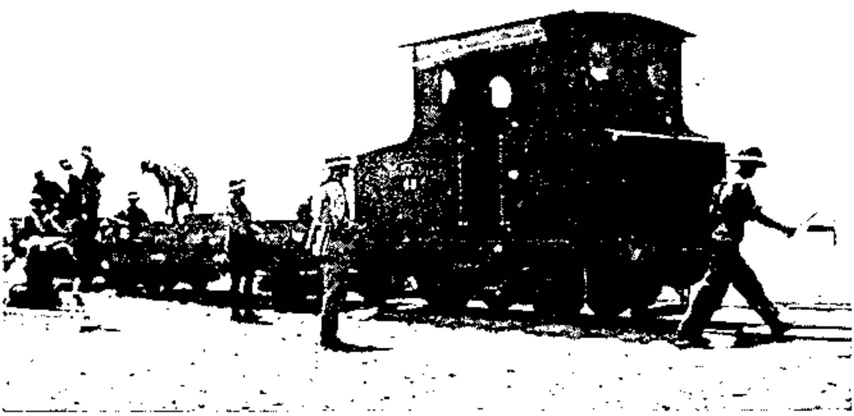
Dear Sir,

War Department Narrow Gauge Railways—1914–18 *War*

About a year ago, I wrote to you asking about the WD light railways used on various fronts during the 1914–18 War and you very kindly published my letter, to which I received several interesting replies.

Since then, I have almost completed my research into the technical side of these railways but have obtained little more historical information from the point of view of those who actually operated and used them. Any account must be rather dry unless one can include this kind of material and so I will be grateful if you will once more allow me to use your columns to appeal for help. I would very much like to hear from any of your readers who have recollections of these lines—either information, or anecdotes or old photographs. Any material will be most carefully handled and returned. No matter how small or vague the recollection may be it will be of interest.

Perhaps, too, your readers could clear up a specific point for me. In the official archives is the enclosed photograph. All that I know is that it is taken somewhere in the Egyptian theatre of war and that the stock appears to be standard RE 2 ft 6 in gauge equipment of the period. Can anyone identify the locomotive or shed any other light upon the scene. The locomotive appears to be petrol driven and bears the number 68.



I hope, sir, that you will be able to help me.

Yours faithfully,

W. J. K. Davies.

Blue Lattice,
Commonfields,
West End,
Woking, Surrey.
30 September 1960.

The Editor,
RE Journal.

Dear Sir,

The Package Deal

I am uncertain whether Sir Arthur Dean disbelieves in the existence of the "Package Deal" or merely objects to the system. If it is the former, a short examination of the advertisement pages of the leading technical journals will show that Messrs X.Y.Z "offer a complete engineering service from the preliminary investigation . . . to the management of the completed works".

I am unaware of any impropriety in accepting speculative remuneration: and since the RIBA permit their Fellows and Associates to accept salaried appointments on the staffs of contractors, they must of necessity accept that such of their membership will be loyal and faithful servants of these masters.

The two disadvantages to which Sir Arthur objected, namely the absence of a satisfactory design staff in a contractor's organization and the profit motive, may have been true forty years ago when as a young man he left these shores. But today the design staff maintained by the larger contractor is enormous and their continuous employment is a serious problem for personnel management. Of course a contractor is in business for his financial advantage: but can Sir Arthur introduce me to a consultant who is not equally concerned with his fees?

It would also be interesting to know who Sir Arthur Dean considers to be the most important of the consulting engineer's assistants, if not the quantity surveyor.

In conclusion, not only am I neither a contractor's man nor a budding consultant, but I am not the servant of a potential client either. I have endeavoured to write of a new system impartially and dispassionately and am unable to understand Sir Arthur's suggestion of denigration, nor do I believe that the majority of members of the Institution, on re-reading the original article, will accept that I provoked such a remark.

Yours faithfully,

D. M. R. Esson, Major.

Brigadier Sir Mark Henniker, Bt, CBE, DSO, MC.
Newport, Mon.
10 October 1960.

The Editor,
RE Journal.

Dear Sir,

Walking Out Dress for Soldiers

For some obscure reason a large section of the young men of today fancy themselves in drain-pipe trousers, coloured waistcoats and long coats. They also cultivate long hair. Psychologists may be able to explain this, but ordinary people will confirm that these garments are today fashionable amongst young people. For purposes of this letter the reason is not important. What does seem important is to avoid ignoring a fashion one does not admire: it would be better to take advantage of the fashion, and design a walking-out dress for soldiers that adopted its features and so secured recruits.

The Blimps will hold up their hands in horror; but they may be wrong. Let us look at the military uniforms of yesteryear. You see in military prints of 100 years ago soldiers in skin-tight pantaloons, with long coats cut away at the waist and laced with colours; and the soldiers wore wigs or pigtails.

Why not something like this today? Why not overall trousers like the mess kit o. my own generation? Why not a red or blue or yellow etc waistcoat according to regiment or corps? Why not a coat that is long with buttons that may be worn done up or open with decorum so as to display the waistcoat? And why not a white shirt and a coloured tie! I must confess that even I rather boggle at long hair: but really, when you think of it, why not? Of course it may be unhygienic; and for active service a crew cut is much better; but if the Army provides hot water in barracks it is reasonable to suppose it will be used; and the Army Act can always be invoked if the soldier's turn-out on parade is unsatisfactory—which includes a dirty crop of hair.

It seems to me that the Army could more easily produce a decorous walking-out dress embodying the features of tight trousers, long coats and fancy waistcoats that it can produce on embodying the conventional cuts of today. Moreover the suit I have in mind is hallowed by ancient custom and tradition.

Would it be worthwhile to set as a subject for one of the Military Prize Essays the subject: "A Walking-out Dress for Soldiers, bearing in mind the connexion between the uniform of the soldier and recruiting"?

Yours sincerely,

M. C. H. Henniker.

Book Reviews

THE TWO TYPES

By Jon

(Published by Ernest Benn Ltd. Fleet Street, EC4. Price 5*s*.)

Ernest Benn Limited have just published a booklet containing a series of cartoons by "Jon" of the famous "Two Types" of the North African and Italian campaigns, with a foreword by Field Marshal Earl Alexander of Tunis.

The originals of these cartoons appeared regularly, as many will remember, in the *Eighth Army News* and later in the *Union Jack*. Jon's drawings portray the exploits of two young captains, one from the tanks and the other an infantryman. Like many thousand others they left England towards the end of 1940, soldiered continuously through North Africa, Sicily and Italy with an excursion into Greece without any home leave until their age and service group came up at the end of the war. Their nostalgic ideal of comfort and luxury was the flesh pots of Egypt and Cairo and Groppi's in particular. Their Egyptian-made suede "creepers" and corduroy trousers, coloured stocks and originality and functionalness of their dress became proverbial. It was also on numerous occasions imitated when it provoked official displeasure. The Two Types themselves, however, never caused any displeasure. They made light of the most appalling conditions without a hint of martyrdom or of heroism and their unaffected friendship through moments of extreme danger and discomfort, and of very occasionally comparative luxury, epitomized the spirit of good comradeship that prevailed throughout the British troops in their long struggle from Egypt to Austria. And, of course, the cartoons were splendidly drawn, genuinely funny and were masters in the art of understatement. If ever a man deserved a good mark, a medal or any other form of recognition for maintaining the morale of the troops each day, Jon certainly did.

This little book of drawings would make an ideal, and inexpensive, Christmas present for any one time Middle East warrior, particularly if he once had sand in his hair.

J.L.

BOTH SIDES OF THE HILL

By Jan and David Kinche

(Published by Secker & Warburg. Price 25*s*)

This is the first book on the Palestine War of 1948 which tries deliberately to avoid all attempts at special pleading. The authors have spent some years in checking the still unpublished Israeli archives and they were given also access to secret private papers of the commanders and the Prime Minister. They also were able to consult the minutes of the Arab League Council meetings, and they interviewed many of the principal British officers and politicians concerned with the final British phase in Palestine.

As a result the reader is able to check one against the other, and the authors conscious of their own bias have been largely successful in controlling it. For the first time, then, we can see what really went on in Downing Street, inside the Arab League and in the minds of the Jewish leaders. The result is exciting and different. The blame lies not so much on Ernest Bevin, in the opinion of the authors, as on Attlee. The British officers are treated with scrupulous fairness and their dilemmas and difficulties emerge very clearly. General Glubb, however, comes out less well. He did not seem to be as completely in the picture as he had imagined. King Abdullah did sometimes suspect that Glubb was still too much an Englishman. The King's own role was very different from that which has been hitherto ascribed to him. He was one of the principals urging a solution by arms, while the Egyptians were opposed to the invasion of Palestine until ten days before the event.

Altogether this is a book which compels a radical revision of all opinions hitherto held about the Arab-Jewish war of 1948. J.B.

REINFORCED CONCRETE RESERVOIRS AND TANKS

By W. S. Gray

Fourth Edition Revised by G. P. Manning

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

This is a well-known work on reservoirs and tanks and has been brought up to date to conform with the new code on liquid retaining structures (CP 2007 (1960)), but remain very similar to the previous edition.

The chapter on open reservoirs with counterforted walls has been extended and a useful graph has been included to give bending moment coefficients for the calculation of moments in walls, monolithic with the bottom of the tank but unsupported at the top, spanning between the counterforts.

The chapters on covered tanks, constructional methods, and repairs have been extended. Included with the appendix on the new code of practice is a series of useful design graphs but enough attention is not drawn to these in the text.

When the new code was produced I feel that the opportunity should have been taken to redesign and modernize the book rather than revise it as it now tends to be old fashioned; there is, for instance, no reference anywhere to prestressed construction. However, it is still a useful reference book for the reinforced concrete designer.
W.C.

Technical Notes

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada*, August 1960.

"Aqueduct and pumping station for Greater Winnipeg": Since 1919, the water supply to Greater Winnipeg has been taken from Shoal Lake, at the western end of Lake of the Woods, through an aqueduct 97 miles in length. From the intake the first 80 miles is a gravity flow section, mainly of horse-shoe cross section, and built in plain concrete. A pressure section, 4 miles long, built in 8-ft diameter reinforced concrete pipe, extends the aqueduct to Deacon, at which point a new branch pipeline, of 66 in diameter, is now being constructed to serve a new reservoir at the southern limit of Greater Winnipeg, with provision for the future installation of booster pumping.

This paper describes the preliminary design of the project, and sets out very clearly the general design of the new pipe-line and the alternatives considered. The constructional methods adopted by a most efficient contractor are also discussed, and some interesting details are given about the construction of the tunnel crossing of the Red River, and of the design of a new low-lift pumping station now under construction at the aqueduct intake.

"The Khulna newsprint project": Khulna is a growing industrial town in the middle of the delta of the Ganges and the Brahmaputra. The development of a sound economy in East Pakistan is a peculiarly difficult problem, because of its comparative isolation, inadequate transportation system, and lack of industrial resources. The main interest in this paper lies in the very thorough preliminary investigations of forest resources and pulping properties, of physical requirements, and of economics.

The whole task was entrusted to Canadian engineers and contractors who, despite the absence of suitable local materials, and the unaccustomed replacement of much mechanical plant by human labour, contrived to finish the job substantially on schedule. The plant is in production, and the quality of newsprint and printing papers appears to assure a ready market.

"The economics of an industrial gas turbine": At the university of Alberta a small gas turbine (output 2,000 kW approximately) has been installed as a source of electric power during the short daily peak period. The primary economic consideration was the high cost of the local authority's supply, based in part, as is quite common practice, on the maximum demand by the customer, however short the period of that demand. The discussion of the economic considerations is interesting, and the installation, and its value for instructional purposes, are briefly described.

"Joints in precast concrete building frames": The use of precast members in a structure can save time and labour, primarily by avoiding the necessity for form-work, but the strength of the structure, and the real economy in effort, depend largely on the methods of joining members together.

This is a clearly written discussion of both the technical and the economical aspects of jointing, with a description of certain designs worked out by the author. The difficulties of welding reinforcing steel are pointed out.

Any engineer concerned with the erection of steel and precast RC structures should be able to acquire useful knowledge and ideas in the short time needed to digest this paper.

Notes from *The Engineering Journal of Canada*, September 1960.

"THE PRINCIPLES OF AUTOMATIC CONTROL": The marriage of automatic control (servo mechanisms) and automatic computers took place during World War II, in the design of automatic fire control equipment. In the past ten or twelve years, both analogue and digital computers have become readily available to control system engineers, and the present trend is towards the complete integration of accurately computed information with complex multi-variable control systems.

The introduction of this paper is encouragingly comprehensible, but the technical discourse which follows is unlikely to benefit those without specialist knowledge.

"WATER SUPPLY AND SEWERAGE AT URANIUM CITY": An interesting account of the development of Aklavik, in NW Canada, was given in *The Engineering Journal* for January 1960 (see *RE Journal* June 1960). A somewhat similar problem had to be faced at Uranium City, in northern Saskatchewan, where no road or railway exists within 100 miles. Barges can be used for transportation from railhead only between early June and mid September: at other times air transport must be employed. This paper deals almost exclusively with the design and construction of water supply and sewage systems, and it describes the techniques used for the heating and recirculation of the distribution loops. In the service connexions to buildings the sewage outfall and water supply are laid together, both being insulated, and an electric heating wire, taken through a transformer from the house supply, is used during the coldest period. It is claimed that arctic regions can, in the light of experience, be served at reasonable costs.

"AIR PHOTO INTERPRETATION IN MUNICIPAL ENGINEERING": In March 1959, *The Engineering Journal* published an interesting paper on "Photogrammetry in highways and railways engineering" (see *RE Journal* September 1959). That paper made some rather surprising claims regarding the class of detailed information obtainable by modern techniques of photo interpretation. The application of these techniques to the smaller scale requirements of municipal engineering is now clearly summarized, and the authors are careful to point out, first, that the data obtained must be separated into three distinct categories—facts, inferences, and speculations—and, second, that photo interpretation, while it will often drastically curtail field work, cannot be regarded as a substitute for it. This is a thorough and well presented statement of the manifold applications of a highly developed art in the planning stages of a project. It is not concerned with the techniques of interpretation, but it does seek to inform the practical engineer what the specialist can produce for his use.

"THE DUNVEGAN SUSPENSION BRIDGE": The Dunvegan suspension bridge across the Peace River in Alberta is the fourth largest suspension bridge in Canada, though the greatest clear span of 900 ft is relatively short. The main interest of this paper lies in the measures taken to deal with particular climatic conditions and the geological structure of the river bed and banks. Owing to the difficulty of driving sheet piling, the method of constructing the two river pier bases was unusual, the northern one involving the sinking of a caisson 86 ft × 30 ft, with reinforced concrete walls 5 ft thick. The stiffening trusses are Warren-type girders, 15 ft deep, with double intersecting diagonals, the wind system and bridge deck being at mid-depth. Methods of calculation are described, and the design constants are given in an Appendix. Another Appendix sets out an analysis to determine the theoretical buckling load for a tower leg. R.P.A.D.L.

THE MILITARY ENGINEER

JULY–AUGUST 1960

"Water for the Future", by Lieut-General E. C. Itschner, United States Army Chief of Engineers. The Chief of Engineers reviews the work which has been engaging the Corps of Engineers co-operating with the Senate Select Water Resources Committee in an effort to estimate future national water resources needs and how to meet them.

The subject includes both the improvement and development of water ways, the provision of domestic water, and of the immense quantities which will be required by industry. Without going into detail a comprehensive picture of the problem is drawn.

"Panmunjom Today" by M. O. Smith. A brief well illustrated account of the accommodation which has been built in the demilitarized zone in Korea.

"Hangar on Wheels", by Lieut-Colonel E. E. Bennet, Corps of Engineers. A description with illustrations of how a 146 × 162-ft steel arch truss hangar weighing 80 tons was moved on wheels from one position to another at an airfield in Saudi Arabia.

"Troop Construction in Germany" (A rifle range at Ettlingen), by Colonel Lawrence E. Lynn, Corps of Engineers. A description with design details of the construction of the rifle range which included a reinforced concrete protective wall faced with timber 706 ft long and 17 ft high instead of the usual earth butt. The wall was built of H columns at 15 ft centres with slots 6 in deep and 12 in wide to take precast RC slabs 13 ft long and 10 in thick.

"Protective Construction". (A Summary.) The subject of the Symposium of the Society of American Military Engineers held as part of the 40th Annual Meeting was "Protective Construction". This article is a series of digests of the papers presented by officers of the Army, Navy, and Air Force and officials in research and industry. The papers deal with general principles, describe research work in progress and show in outline the various types of structure which can be used for different objects. The great cost of wide dispersion will often make the provision of physical protection more economical but military planners and designers must participate in the research and development phases of the particular weapons systems to be enabled to contribute the best possible solution to the problem of providing the best protection. There is no indication in the article of the extent to which the protective structures described have been brought into use.

"Shelters for Survival", by Lieut-Comdr W. J. Francy, Civil Engineer Corps United States Navy. This is a summary, with good illustrations, of the main results achieved in the United States Government programme of research development and testing in the field of shelters. The programme has produced information necessary to prepare designs for both blast and fall-out shelters, many of which are now available. The various types of shelter are described in detail and the effects of tests in conjunction with trials of atomic weapons are given.

"Ethiopian Survey Operations", by Rear Admiral H. Arnold Karo, Director, Coast and Geodetic Survey. The United States and Ethiopia made an agreement in 1956 under the International Co-operation Administration, for a study of the water resources of the Blue Nile watershed in Ethiopia. The establishment of precise horizontal and vertical control throughout the area was recognized as a basic part of the programme. This article describes the way in which this has been carried out and gives the points at which the triangulation has been linked with existing Sudan and Eritrean systems. The article also gives a summary of the nature of the water resources available in the area.

"Flugplatz Tempelhof", by Major Herbert J. Gall, United States Air Force. The Tempelhof Airport in Berlin was designed in 1935 to an entirely revolutionary plan. It was about 80 per cent complete in 1943 but was largely destroyed by allied bombing and Russian occupation at the end of the war.

This article gives an account of its restoration and completion to the original design. It is remarkable how completely it meets the needs of 1960 though conceived in 1935.

"Military Developments in Mufti", by Colonel A. H. Davidson, Jun., Corps of Engineers. This is a summary of various equipments and materials developed by the

Army Engineer Research and Development Laboratories which have been found of use in the civilian world. They include a method of fabricating low cost plastic replica mirrors used in infra-red night-vision equipment, water purification, insecticides, fire fighting and protection, protective coatings of many kinds and packaging. The wide field covered by the ERDL is very striking.

"Four-Stage Free-piston Compressor", by J. G. Coutant. This article describes a liquid-cooled four-stage compressor of unique design. The compressor cylinders are arranged horizontally and the movement of free-floating tandem pistons is synchronized by an ingenious but simple cam- or lever-operated synchronizing mechanism. The pistons compress air when moving in opposite directions. On the return stroke the air is compressed to ignition pressure, fuel is injected, and the compression ignition process takes place.

The article includes numerical analysis including basic data, dimensions, and operating characteristics. The calculations given by the author facilitate the understanding of the basic factors of the design and the advantages of this unit in comparison with conventional compressors and compression ignition engines.

September–October 1960

"Marine Traffic Control in the Panama Canal", by Lieut-Colonel Robert D. Brown, Jun., Corps of Engineers. Operating problems in the Panama Canal have increased in complexity so much over the last few years that a consulting firm was engaged in January 1958 to study the problem and make recommendations for modernizing ship scheduling and surveillance. Their findings have resulted in the adoption of a plan for digital computer scheduling and hyperbolic radio surveillance for canal traffic. This article describes the problems to be solved and the purpose, operation and in broad terms the design of the new devices which are being installed. There are good illustrations and some idea of the change which has taken place in the traffic to be dealt with can be seen from the fact that daily traffic in 1960 was as much as monthly traffic in 1915.

"Engineer District Activities in Korea", by Major Robert E. Rich, Corps of Engineers. This article deals almost entirely with the special problems of carrying out the large programme of construction of every kind of accommodation required for the US army when the decision was taken to make provision for a long stay in Korea. It is interesting to read about the working of the Works Service in the US Engineers but there is very little that is new. There are good photographs of projects in hand and completed.

"Small Gas Turbines for Military Use", by 2nd Lieut Richard P. Chalupa, Corps of Engineers. A very clear exposition of the principles of the gas turbine engine with a summary of its favourable and unfavourable characteristics. Its lightness, ease of starting and relative indifference to weather conditions make it a very attractive power unit for many military purposes. The author foresees its increasing employment as improvements in design reduce its cost to something nearer that of piston engines. There are illustrations of uses to which it is being put.

"The Most Treacherous Iron", by Captain William F. Brandes, Corps of Engineers. This is a short account of the construction of an Air Force tropospheric-scatter radio installation in the wideband system linking Thule with Cape Dyer on Baffin Land. The account is interesting especially for the difficulties imposed by the below zero temperatures and high winds.

"Bases for Deterrence", by Colonel Stanley W. Dziuban, Corps of Engineers. A short article with some illustrations giving an outline of the work being carried out on ICBM sites and anti-missile bases needed for adequate deterrence of enemy attack. There is also some information about the Air Force Ballistic Missile Early Warning

System of which the installation referred to in the preceding article forms a part. The immense cost of the programme is justified on the assumption that it does constitute an effective deterrent.

"Army Gas Cooled Reactor Systems", by Melvin A. Rosen, Captain George A. Bicher, Captain Richard A. Schwarz, Corps of Engineers. This article is a description, in considerable detail, with illustrations and diagrams of the progress being made in the development of a compact, reliable, mobile power plant, free from logistical support in the Army Nuclear Power Programme conducted jointly by the Army and the Atomic Energy Commission. The plant will consist of a gas-cooled reactor and a closed cycle gas turbine power plant. Two experimental units have been erected, the Gas Cooled Reactor Experiment (GCRE) and the Gas Turbine Test Facility (GTTF). From work carried out on these the design of the ML-I (Mobile Low Power Plant 1st Model or prototype) has been developed so far that it is expected that a prototype will be ready for trial in 1961. The unit will be capable of an output 300–500 kW and will be in three main packages weighing 15 tons each and normally transported on military semi-trailers though they can be broken down for air transport.

"Geodesy by Optics and Electronics", by Andrew C. Campbell. A detailed description of the use of electronic distance measuring devices in conjunction with theodolites in the area of Midway Island on a job which could not be carried by either alone. The article is highly specialized but should be of interest to anyone familiar with present-day survey techniques.

"The River Engineer", by Major-General William A. Carter, United States Army. A highly condensed article with gives a remarkably comprehensive picture of the problems met with in the control and use of rivers in general and of certain ones in the United States in particular. J.S.W.S.

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*, September 1960.

"REACTOR SHIELDING". The first part of this article deals with the general shielding requirements, neutron shielding, permissible levels of radiation and thermal and biological shields. Concrete is by far the most widely used material for biological shielding and the thermal properties and thermal stresses of concrete are discussed in detail. Two interesting graphs show thickness of material required to reduce radiation by a factor of ten and gamma radiation as a function of concrete thickness.

"INFLUENCE LINES BY COMPUTER". An electronic digital computer was used to solve an indeterminate structure formed by a continuous beam over several supports. It is claimed that fifty loading conditions on a ten-span continuous bridge can be solved in 8 minutes for a cost of about £8 10s.

"CONSTRUCTING ROADS WITH SOIL AND SAND". An experiment has recently been carried out in Western Australia in constructing roads from soil and sand. Corrugations have always been present in dirt roads but the new technique, it is claimed, eliminates this. The theory is that the road pavement or formation materials are as dense as possible with a low plasticity index. The voids between the larger particles should be filled with a light filler material which is itself stable under traffic conditions.

In the experiment a 3-in layer of imported silt was mixed with 8-in of underlying sand and consolidated with six passes of a 3-ton vibrating roller.

"OTHER ITEMS". Bridges are well featured in the issue, reports on the Tamar Bridge, Throgs Week Bridge, New York, and the launching of 165-ton beams on the Maidstone By-pass Motorway bridge are included.

Articles on buckling of structures, flexure of beams and struts and loading tests on an underreamed bored pile are described.

Notes from *Civil Engineering and Public Works Review*, October 1960.

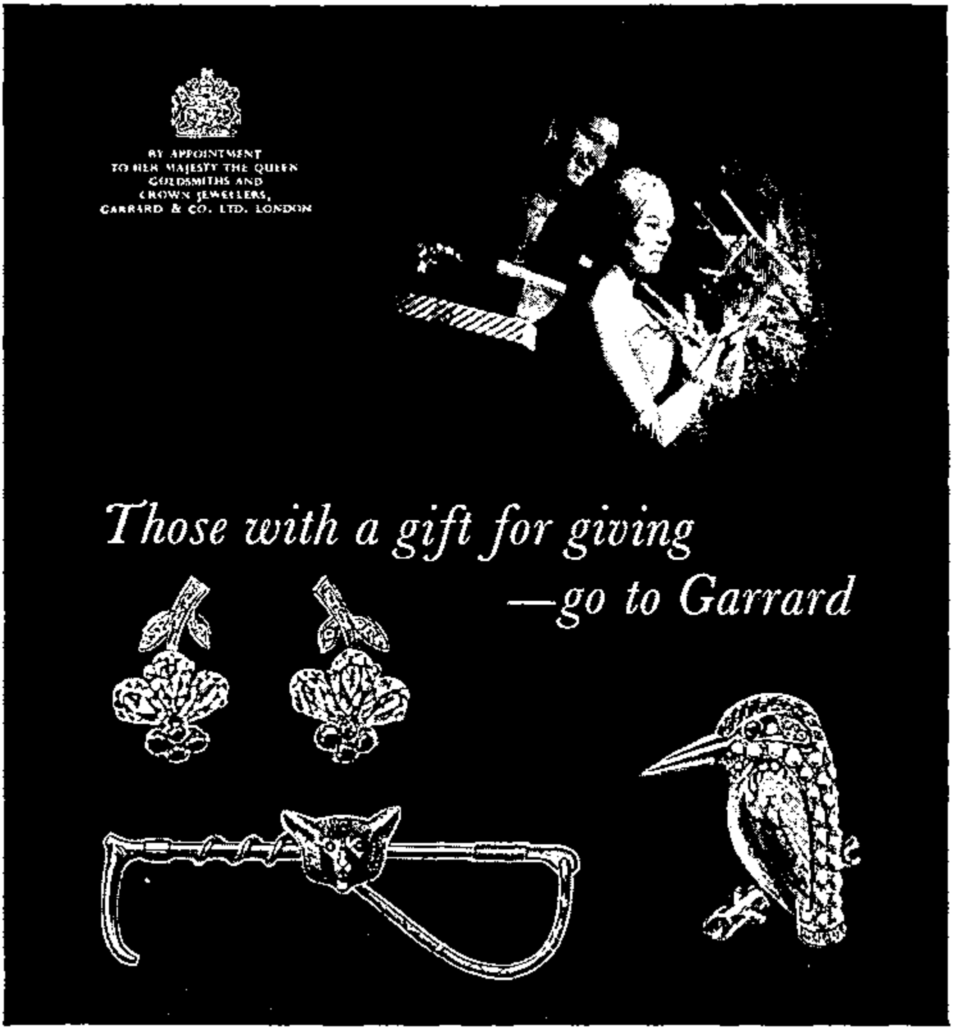
"Protecting Steel Wire in Storage". One problem facing the builders of the new Forth bridge was the preservation of 6,000 tons of galvanized high-tensile steel wire. The article describes the methods and equipment used in doing this.

"Pneumatic Nail Driving on New Zealand Contract". This short article describes the improvisation of a pneumatic nail driver used for constructing laminated timber decking for bridges. Speed comparisons show that four men with claw hammers took 4¼ minutes to nail one length of planking containing sixty-two nails (i.e. 17 man minutes per plank) whereas one man with a pneumatic nail driver took 8½ minutes—a 50 per cent saving.

"Sea Defence Groynes". Part I appears in this issue and contains a summary of the legislation on coast defence. A brief survey of the geology of the British coastline is made which leads on to the sections where sea defence work is necessary. The causes of the movement of beach material is described and the effect that groynes have in stabilizing the foreshore. The types, shapes and materials used in groynes are briefly mentioned and these materials and methods of construction will be considered in subsequent issues.

"Reactor Shielding". Part II of this article deals with heavy weight concrete, about which little appears to have been written in this country. The thermal properties and resistance to radiation of concrete are described. Table I gives useful data on shielding thickness and a graphical derivation of thermal stresses is also given. A chart showing cost of concrete against density is unfortunately given in dollars per cubic yard and one is left wondering if the simple application of a factor makes the graph applicable in Britain.

"The Stability of Long Welded Rails". Part III of the article summarizes the previous two parts and includes three appendices, the first on torsion test machines, the second on lateral moment of resistance and the third on ballast resistance which includes a very comprehensive table of test results. W.C.



Ruby, aquamarine, diamond and platinum earrings. £160 . 0 . 0

Hunting stock retainer, 9 ct. gold, ruby eyes. £16 . 10 . 0

Kingfisher brooch. Sapphire, turquoise, ruby, diamond, enamel and 18 ct. gold. £230 . 0 . 0

The 1960 Garrard gift catalogue illustrates a most impressive variety of suggestions for both personal and mess presentation. For ladies, these range from delightful yet inexpensive gold charms to magnificent suites of jewellery. For men there are watches, toilet accessories, smoker's requisites and many other handsome alternatives.

Wherever you may be, you may choose with confidence from a wide selection of Garrard gifts, each a token of lasting value and impeccable taste.

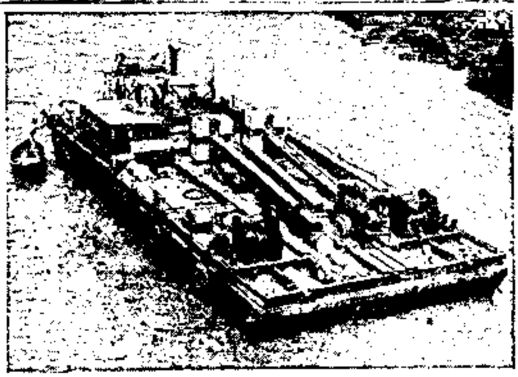
Your copy of "Garrard Gifts" will be supplied free on request.

GARRARD & CO · LTD

Crown Jewellers

112 Regent Street · London · W.1 · Telephone: REGent 3021 (11 lines)

BRAITHWAITE PONTOONS



The first flight of less than one hour in the *Daily Mail* London to Paris Air Race was made from this Braithwaite Pressed Steel Pontoon moored in the Thames.
Braithwaite pontoons can be constructed to any required size and are ideal for harbour construction and similar works.

The power driven pontoon illustrated was supplied to the new atomic power station at Hinkley Point, under construction for the Central Electricity Generating Board by The English Electric, Babcock & Wilcox and Taylor Woodrow Atomic Power Construction Co., Ltd.

BRAITHWAITE & CO. ENGINEERS LIMITED

BRIDGE AND CONSTRUCTIONAL ENGINEERS

London Office:
DORLAND HOUSE · REGENT STREET · LONDON SW1
Telephone: Whitehall 3993 Telex: 23317 Telegrams: Bromkirk Phone London

NAAFI and YOU

"Food for thought"...

R.A.F. Dishforth and R.A.O.C. Donnington. These were the stations originally selected for an experiment which could revolutionise Service catering.

Naafi was given the entire responsibility for providing, cooking and serving all the meals for officers, senior N.C.O's. and men at both places.

The quality and variety of the food and the general standard of the service continue to receive high praise from all ranks.

The success of the experiment has resulted in Naafi's contract being extended to other military establishments.

Another example of Naafi's Service to the Services.

IMPERIAL COURT, KENNINGTON LANE, LONDON, S.E.11

The Official Canteen Organisation for H.M. Forces

HISTORY OF THE CORPS OF ROYAL ENGINEERS

Volumes of this History, covering the period 1066 to 1948, are on sale from the Institution of Royal Engineers, Chatham, at the following rates:—

Volumes I to VII ordered together—price £2 10s. to members, or £10 to non-members.

Volumes IV to VII ordered together—price £1 10s. to members, or £6 to non-members.

Volumes I to VII—10s. each to members of the Institution or 35s. to non-members.

Volumes VIII and IX—15s. each to members of the Institution, or £2 7s. 6d. each to non-members.

G. PERCY
TRENTHAM
LIMITED

BUILDING

AND

CIVIL ENGINEERING

CONTRACTORS

BIRMINGHAM READING
LONDON GLOUCESTER
STOKE-ON-TRENT CARDIFF

WOOD LANE BROMFORD BIRMINGHAM	Erdington 2491
PANGBOURNE READING BERKS	Pangbourne 411
NEW ROAD RAINHAM ESSEX	Rainham 2902
UPTON LANE BARNWOOD GLOUCESTER	Gloucester 66172
PARK HALL LONGTON STOKE-ON-TRENT	Longton 39147
ROATH BASIN BUTE DOCKS CARDIFF	Cardiff 30256

★ ★ ★ ★ ★

FORD FIVE STAR MOTORING

To people going overseas who are considering buying a new car:

To officers proceeding abroad, serving overseas or returning to this country for leave:—

We can offer any of the Ford range of cars Free of Purchase Tax, subject to currency and import restrictions in certain territories. These cars may be used in the United Kingdom for six months prior to exportation. We shall be pleased to send full details on request.

BROOK GARAGE

(CHATHAM) LTD. *Phone 41141*

315 HIGH STREET, CHATHAM, KENT

MAIN FORD DISTRIBUTORS

POPULAR : ANGLIA : PREFECT : CONSUL : ZEPHYR : ZODIAC

The printers of this journal

MACKAYS OF CHATHAM

are at your service for printing, bookbinding and blockmaking

W. & J. MACKAY & CO LTD FAIR ROW CHATHAM

TELEPHONE CHATHAM 42243-5