VOL. LXIX. No. 1 MARCH, 1955

THE ROYAL ENGINEERS JOURNAL

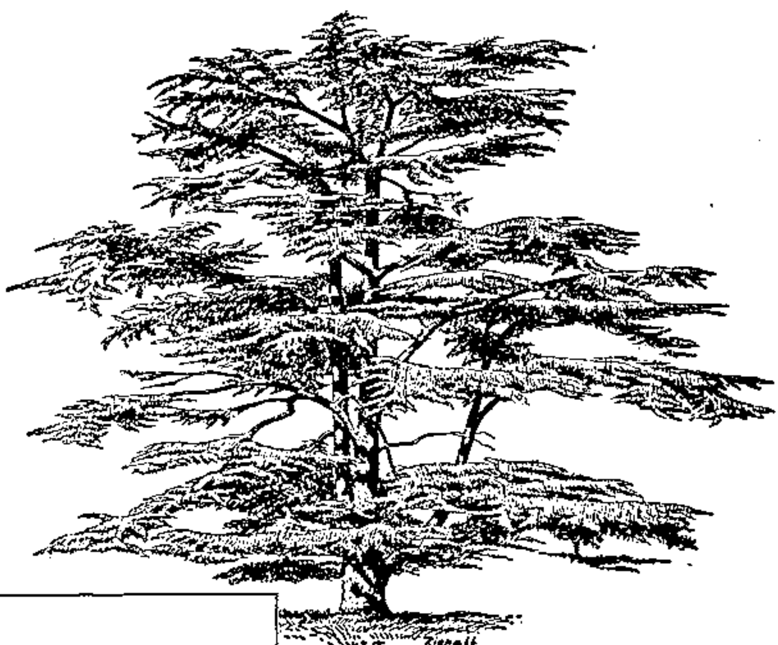
CONTENTS

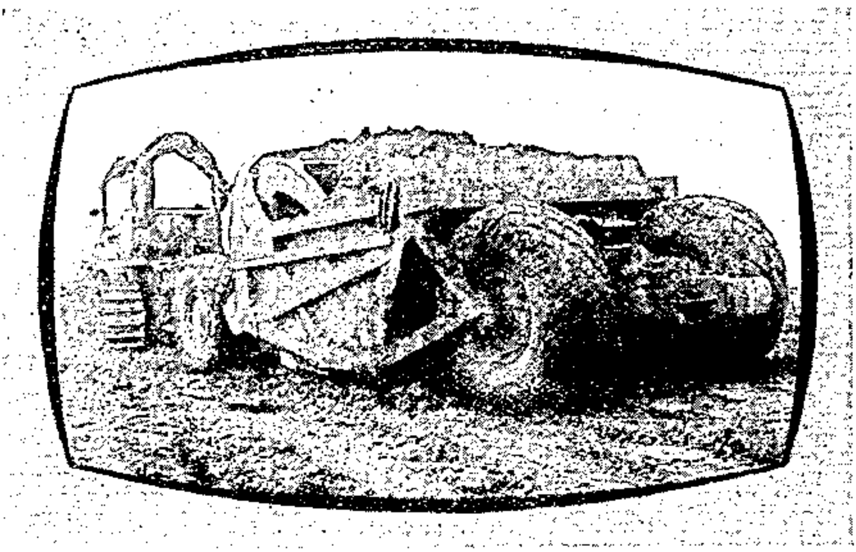
PUBLISHED QUARTERLY BY THE INSTITUTION OF ROYAL ENGINEERS
CHATHAM, KENT Telephone: Chatham 2669

All Correspondence connected with Advertisements should be addressed
THE SECRETARY, THE INSTITUTION OF ROYAL ENGINEERS

AG ... THAM

THE ROYAL ENGINEERS JOURNAL—MARCH, 1955 VOL. LXIX. No. 1





BUILT FOR TOUGH ASSIGNMENTS

WHEELED
SCRAPERS
IN 9 SIZES

TINED
RIPPERS
IN 6 SIZES

C.C.U's
IN 4 SIZES

ALSO SHEEPSFOOT ROLLERS AND PNEUMATIC CONSOLIDATING ROLLERS

The tougher the job the more Onions' equipment rises to the occasion. Operators prefer it for every kind of earth moving project. The SCRAPERS are robust, stable and enduring. CABLE CONTROL UNITS are smooth and light in operation, simple to adjust and maintain. RIPPERS with 3 *or* 5 *tines* use all the power of matching tractors to break every kind of hard ground. With ROOT CUTTER BLADES they clear scrub and sever roots to 30 in. deep. With CULTIVATING KNIFE they break and crumble ground to 24 in. deep without bringing up the top soil.

ONIONS
Empire
EQUIPMENT

Onions' Tractor Equipment is made to match all the leading makes of Tractor, both British and American. On most sites at home or abroad you will find Onions' equipment keeping pace with the best.

Manufactured by **ONIONS & SONS (LEVELLERS) LTD., BILSTON**
Distributed throughout the world by **JACK OLDING & CO. LTD.**

THE ROYAL ENGINEERS JOURNAL

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

VOL. LXIX CONTENTS MARCH, 1955

THE COUNCIL OF THE INSTITUTION OF ROYAL ENGINEERS

(Incorporated by Royal Charter, 27th February, 1923)

Patron—HER MAJESTY THE QUEEN

President

Lieut-General Sir Philip Neame, V.C., K.B.E., C.B., D.S.O.	1954

Vice-Presidents

Major-General I. S. O. Playfair, C.B., D.S.O., M.C.	1954
Major-General J. C. Walkey, C.B., C.B.E.	1955

Elected

Major W. W. Chapman, O.B.E., T.D., A.R.I.B.A.	1952
Colonel J. F. D. Savage, D.S.O., B.A.	1952
Major-General J. F. D. Steedman, C.B.E., M.C.	1952
Brigadier A. G. Bonn, C.B.E., M.C., M.I.C.E.	1953
Major J. R. Cave-Browne, M.C., B.A.	1953
Lieut.-Colonel I. H. Lyall Grant, M.C., M.A.	1953
Brigadier K. Mackay, D.S.O., O.B.E.	1953
Captain J. A. Notley, M.B.E.	1953
Brigadier H. P. Drayson	1954
Lieut.-Colonel F. E. Ladly M.B.E., E.R.D., M.R.San.I., A.I.Mun.E.	1954
Brigadier J. K. Shepheard, D.S.O., O.B.E., B.A.	1954
Colonel W. B. Sykes, T.D., M.I.Struct.E., M.Soc.C.E. ...	1954
Major-General B. T. Wilson, C.B., D.S.O.	1954
Major E. L. Wilson, M.C.	1954

Ex-Officio

Brigadier T. I. Lloyd, D.S.O., M.C.	D.E.-in-C.
Colonel G. C. Clark, O.B.E.	A.A.G., R.E.
Brigadier H. C. W. Eking, C.B.E., D.S.O.	Comd., S.M.E.
Brigadier G. J. Bryan, C.B.E.	D.Tn.
Major-General D. C. T. Swan, C.B., C.B.E.	D.F.W.
Brigadier L. D. de V. Carey, C.B.E.	Dir. of Mil. Survey
Colonel E. N. Bickford	D/Comd., S.M.E.
Brigadier F. W. Houghton, D.S.O., M.C.	Comd., Trg. Bde., R.E.

Corresponding Members

Lieut.-Colonel A. R. Currie, D.S.O., *New Zealand Military Forces*	1st January, 1949
Colonel E. H. Webb, D.S.O., C.D., *Canadian Army*	1st November, 1954
Colonel K. T. Gilson, D.S.O. *Union Defence Force, South Africa* ...	1st January, 1952
Brigadier R. R. McNicoll, *Australian Military Forces* ...	1st September, 1952

Secretary and Editor R.E. Journal

Brigadier C. C. Phipps, C.B.E., M.C.	13th January, 1945

Bankers

Lloyds Bank, Ltd., Cox's and King's Branch, 6 Pall Mall, S.W.I.

4,000. 1.3.55

INSTITUTION OF ROYAL ENGINEERS

CONDITIONS OF MEMBERSHIP

1. The following officers are entitled to Full Membership of the Institution :—

   (*a*) All serving or retired regular commissioned officers of the Corps of Royal Engineers.

   (*b*) All officers serving, or who have served, in the Royal Engineers branch of any of the auxiliary forces in the U.K., such as Army Emergency Reserve, Territorial Army, Supplementary Reserve, Special Reserve or Militia, etc., or who hold, or have held, short service, temporary or emergency commissions in the Corps of Royal Engineers.

   (*c*) All officers serving, or who have served, in the engineer arm of the land Forces, whether permanent or otherwise, of :—

   (i) The Commonwealth.

   (ii) The Colonies or Dependencies.

   Recommendations for Membership of such overseas officers to be submitted through the Senior Engineer Officer of their country.

2. All officers referred to in sub-paras (*b*) and (*c*) above, shall be eligible for Associate Membership instead of Full Membership, if they so desire. Civilian officers of the British Works Services Staff are also eligible for Associate Membership, if recommended by the Senior Engineer Officer of the Command in which they are serving.

3. The entrance fee and annual subscriptions are as follows :—

FULL MEMBERSHIP—

Entrance Fee	£1
Annual subscription (based on subs. rank) :—	
2nd Lieutenant	£1
Lieutenant	£1 5s.
Captain	£1 10s.
Major	£1 15s.
Lieut.-Colonel and upwards	£2
Q.M. or E. & M.O. of any rank ..	£1 5s.

ASSOCIATES—

No entrance fee.	
Annual subscription	£1

4. Full Members receive *The Royal Engineers Quarterly Journal*, *Monthly Supplement to the R.E. Journal*, and *R.E. List*, and free issues of such other Institution publications as the Council may from time to time determine.

5. Associate Members receive free copies of the *R.E. Quarterly Journal*, but not the *Monthly Supplement* or the *R.E. List*.

6. All other publications issued by the Institution, as well as extra copies of free issues, may be purchased at reduced rates by both Full and Associate Members.

7. Associates have no voice in the management of the Institution.

8. All Members resident in Europe are entitled to the free use of the R.E. Library, including free postage one way.

"In olden times the cry 'Follow the Sapper' was the order to advance through the trenches to the assault of fortresses; and in modern warfare it is once more the Sappers who have the task of clearing gaps in the enemy's minefields and guiding the infantry through them. It is the Sappers upon whom the rest of the Army relies to overcome for them any physical obstacles the enemy or nature puts in the way; to make bridges and roads; to provide supplies of water; and in a hundred different ways to make easier the tasks of the troops in the field.

"There is, therefore, a very intimate association between the infantry in any formation and its engineers; and it is very right and proper that the Gurkha Division should now have its own Divisional Field Engineer Regiment.

"The Corps of Royal Engineers is very proud of its newest sons; and I have the greatest pleasure in asking your Major-General to accept this statuette of a Sapper as a token of comradeship and to commemorate the raising of the first unit of Gurkha Engineers."

A translation in Burkhali was then read by the Gurkha Major and the statuette handed to the Major-General, the Brigade of Gurkhas.

In his reply Major-General L. E. C. M. Perowne, C.B., C.B.E., the Major-General the Brigade of Gurkhas, thanked the Corps of Royal Engineers and said:—

"Brigadier Whitman and representatives of the Royal Engineers.

"It is my privilege as their Major-General to express to you on behalf of all ranks of the Brigade of Gurkhas our sincere thanks to the Corps of Royal Engineers for this enduring symbol of their friendship.

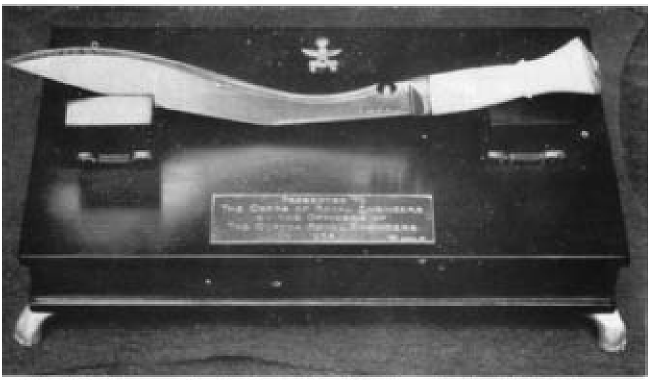
"It is to me a double honour to be, on this occasion at once a Sapper and a Gurkha; and to receive from your hands this present from my own Corps to the Brigade with which my life has become so intimately connected.

"You have reminded us of the extent to which the other arms depend for their ability to live and to fight upon the engineers; and we, for our part, are very conscious of the need for the closest union between the infantry and their sappers. We are, therefore, happy to have brought forth and nurtured the nucleus of our own Gurkha Sappers and proud to know that they are greeted as honoured members of the family of the Corps of Royal Engineers.

"We would like you, and the whole Corps, to know that this figure will be treasured by us and our successors for ever, not only as a thing of beauty and value, but as a sign of the bond of friendship forged between the Brigade of Gurkhas and the Corps of Royal Engineers, and as a constant reminder of the dependence of infantry soldiers upon the closest support of their Sappers."

The Gurkha recruits put on a magnificent parade. The Sapper recruit parties marched past in really first-class style. Later in the morning there was a conducted tour of recruits demonstrating

Silver Statuette of Sapper in working dress of about 1870, presented to the Brigade of Gurkhas



Silver Kukri presented to the Corps of Royal Engineers by the Gurkha Engineers

Presentations

PRESENTATION OF A SILVER STATUETTE OF A SAPPER TO THE BRIGADE OF GURKHAS FROM THE CORPS OF ROYAL ENGINEERS

By BRIGADIER B. E. WHITMAN

THE Corps has presented a Silver Statuette of a Sapper to the Brigade of Gurkhas as a token of comradeship between the Royal Engineers and the Brigade of Gurkhas and to commemorate the raising of the first unit of the Gurkha Engineers.

The presentation was made, on behalf of the Corps, by the Chief Engineer, Far East Land Forces. The occasion was 1st October, 1954, the annual passing out parade of 585 Gurkha recruits at the depot at Sungei Patani in North Malay. There were many senior Gurkha officers at their depot for their annual conference and they attended the parade. Sapper officers with the Brigade of Gurkhas who were present included:—

Major-General L. E. C. M. Perowne, C.B., C.B.E.
(Major-General the Brigade of Gurkhas.)
Brigadier M. C. A. Henniker, D.S.O., O.B.E., M.C.
(Commanding 63 Gurkha Infantry Brigade.)
Lieut.-Colonel J. H. Carver, R.E.
(Commanding 50 Field Engineer Regiment.)

Officer spectators and the massed bands of 110 Gurkha pipers and drummers wore No. 3 dress. 50 Field Engineer Regiment Pipe Band looked very well with their new drums, plaids and No. 3 dress. After an early morning shower the sun shone and the bands and troops on parade presented a colourful spectacle.

For the presentation, the Chief Engineer FARELF, Brigadier B. E. Whitman, was supported by a party of British and Malayan other ranks commanded by Captain J. F. Bennie, R.E., whilst the Brigade of Gurkhas had a similar party of Gurkha Sappers, under Captain J. D. Orange-Bromehead, R.E., formed up behind their Major-General. The Chief Engineer said:—

"General Perowne, officers and men of the Brigade of Gurkhas.

"It is a great honour for me, as Chief Engineer, Far East Land Forces, to have been charged by the Chief Royal Engineer with the pleasant duty of handing over to you, on behalf of my Corps, this piece of silver.

"On many occasions throughout their long history it has been the proud privilege of Sappers to lead the infantry to the assault; and by their support to enable armies to move and to live on the field of battle.

various forms of their training. The Gurkha R.E. recruits were in two parties, one climbing over obstacles in marching order and the other doing a P.T. display. In the evening during a cocktail party for the officers and guests, the massed pipes and drums gave an excellent display of marching and counter-marching in a floodlit arena with a background of two large illuminated crossed kukris and the regimental badges of the Corps of Royal Engineers, Royal Corps of Signals and the four infantry regiments of the Brigade of Gurkhas.

Besides the Chief Engineer FARELF, several other R.E. officers, including Brigadier W. F. Anderson, M.B.E., M.C., Chief Engineer Malaya Command, attended as guests of the Brigade of Gurkhas and enjoyed Gurkha hospitality, which is second to none.

PRESENTATION OF A SILVER KUKRI TO THE CORPS OF ROYAL ENGINEERS BY THE GURKHA ENGINEERS

By BRIGADIER C. C. PHIPPS, C.B.E., M.C.

ON the 24th November, 1954, the Gurkha Engineers presented a beautifully designed silver Kukri to the Corps. The ceremony took place in the R.E. H.Q. Mess at Chatham during a large guest-night, attended by the Nepalese Chargé d'Affaires, Subba Iswary Raj Misra, and the Nepalese Military Attaché, Major-General Sridhar Shamsher Jang Bahadur Rana, as well as over 150 Dominion and Royal Engineer officers from all over the world who were attending an E.-in-C's. Conference.

Colonel F. M. Hill, C.B.E., in presenting the Kukri on behalf of the Gurkha Engineers explained how the first Gurkha Engineer unit, the 67th Field Squadron, had been formed in Malaya during 1948 and 1949 from volunteers from the old Gurkha Infantry regiments. After a comparatively short spell of training in Malaya the unit had been sent to Hong Kong, where they had to carry out many duties in addition to continuing with their engineer training.

By the end of 1950 a second unit, the 68th Field Squadron, was also formed and it too was sent to Hong Kong to join the former unit and to form the 50th Field Engineer Regiment.

The men had responded very well, in what to them, was a completely new form of training.

Colonel Hill said that the Gurkhas were very proud of their association with the Corps and to show their appreciation and affection to the Corps they wished to present the silver Kukri, which was a model of their well-known national weapon and which was represented on their divisional sign.

Lieut.-General Sir Philip Neame, V.C., K.B.E., C.B., D.S.O., the Representative Colonel Commandant, R.E., in accepting the

Kukri on behalf of the Corps said how much he welcomed the presence of the Nepalese Chargé d'Affaires and the Military Attaché, who had made a special effort to be present, and also the officers of the Dominion Engineers as well as those of the Brigade of Gurkhas and of the United States and French Armies.

He explained how every Gurkha Regiment of the old Indian Army was represented among the volunteers for the Gurkha Engineers and ranks ranged from rifleman to havildar and many of them had had up to twelve years service in the infantry.

He himself was particularly pleased to be able to accept the Kukri as he had at one time or another known nearly every Gurkha Regiment in many parts of India and Waziristan and he quoted instances of friendly rivalry between the Sappers and Miners and the Gurkhas.

FREEDOM OF THE BOROUGH OF ROWLEY REGIS GRANTED TO 215 PLANT SQUADRON R.E. (T.A.)

By Captain T. W. M. Ely, R.E.

THE Borough of Rowley Regis, Staffordshire, celebrated its 21st anniversary in October, 1954, and, as part of these celebrations, conferred the honour of the Freedom of the Borough upon its only military unit—215 Plant Squadron R.E. (T.A.). Relations between the borough and the squadron have been close for several years and the unit was "adopted" in 1953.

The Freedom was granted at a ceremonial parade held in Haden Hill Park, Staffs, on Saturday, 16th October, 1954, when the Deed of Grant was formally presented by the Mayor.

The squadron was drawn up in the park opposite the terrace of Haden Hill House with the O.C., Major F. E. Hall, T.D., R.E. (T), as parade commander. The band of the 5th Battalion South Staffordshire Regiment was drawn up in the rear.

The Mayor, Alderman T. Woodward, accompanied by the C.O. 127 Construction Regiment, Lieut.-Colonel J. L. Osborne, M.B.E., T.D., R.E. (T), took the salute and then inspected the squadron. Prayers were said by the Mayor's Chaplain and the Deed of Grant was then read by the Town Clerk. The Mayor addressed the parade and presented the Deed to the O.C. who then replied. An escort of a subaltern and two sergeants collected the Deed and marched off to the Council House.

The squadron marched past the Mayor and through the borough, exercising their newly granted privilege of having bayonets fixed and bands playing. The Council then entertained the squadron at tea.

THE DHEKELIA PROJECT (continued)

By LIEUT.-COLONEL J. D. EDGAR, A.M.I.C.E., R.E.

(Readers should note that this article was written in the autumn of 1953, but publication has been unavoidably delayed.)

TECHNICAL ASPECTS

1. *Responsibilities for Design*

Hitherto in this narrative reference has been made only to Alister MacDonald as architect responsible for designs. However, the D.F.W. in the War Office also employs a large body of highly qualified architects and it was laid down very early on that the War Office was to produce a range of standard sub-tropical designs for use in all permanent new construction in the Middle East, and, of course, that these designs were to be used at Dhekelia wherever possible. The War Office Standard Designs cover the following buildings:—

Barrack blocks.
Major and minor unit messes, cookhouses and junior ranks clubs.
Regimental H.Q. and company offices.
Guard houses.
M.I. rooms.
Band rooms.
Gymnasia and sports pavilions.
Married quarters, both officers and O.Rs.

and any others for which a possible multiplicity of use could be foreseen.

Thus Alister MacDonald was left only with those buildings of a specialized nature and for messes whose numbers of living and dining members failed to adapt themselves to a major or minor unit. The administrative area, with its heterogeneous mixture of small units and large assortment of specialized functional buildings naturally gave Alister MacDonald pride of place in design work for the first contract; but even so, besides the obvious barrack blocks, it was found possible to include W.O. Standard Designs for two major unit sergeants' messes (see Sketch 1) an O.Rs'. cook-house, M.I. room, junior ranks club and guard house. In later phases of the project, in particular those for the married quarters and major unit lines, W.O. Standard Designs gain considerable prominence, but Alister MacDonald comes very much into his own again with the B.M.H. and attached messes, the town centre and other garrison amenities. There is thus provided plenty of opportunity for effective contrast between two highly differing styles. W.O.S.D. buildings are usually symmetrical, massive in feeling, with hipped roofs of steep pitch; Alister MacDonald, on the other hand, favours almost complete assymetry, low pitched gable-ended roofs and, wherever possible, contrasting variations of wall treatment (compare Sketches 1 and 2). There is no doubt about the two styles blending effectively, especially since Alister MacDonald is entirely responsible for layouts and external colour treatment of all buildings, and it will all add to the architectural interest of the cantonment.

Messrs. Davson & Prichard, quantity surveyors, produce all bills of quantity for Alister Macdonald's designs, whilst W. J. Tillyard does the same for W.O.S.Ds. It was originally proposed that Davson & Prichard should send out a team to Cyprus to assist in the execution of the first contract, since it was foreseen that the consequences of the rushed and dovetailed planning would require a good deal of ironing out when it came to the actual building. However, this did not materialise, and there has to be an extra strong quantity-surveying team on the C.R.E's. staff under a S.Q.S. and these have been kept inordinately busy sending back to London for taking-off sheets and trying to square the many discrepancies that keep appearing between drawings and B.Qs.—for which, as I have stressed before, neither Alister MacDonald nor Davson & Prichard can be in any way to blame.

For structural engineering design work on special buildings, the War Office employed Messrs. Scott & Wilson, Mr. Iorys Hughes, Messrs. S. H. & D. E. White and Travers Morgan & Partners, all of whom have co-operated most closely and felicitously with Alister MacDonald's office.

Civil engineering works are in general designed by Messrs. Scott & Wilson, but Messrs. Binnie, Deacon & Gourlay are consultants for the supply of water, from where it comes out of the ground to where it enters the cantonment and this firm also designed the trunk sewer from the administrative area to the outfall. This split in responsibilities is perhaps unfortunate, but implies no reflection on the abilities of either firm; it just so happened that War Office wanted designs for the "external" water supply system and trunk sewer pushed on, in advance of the detailed layout of the administrative area and for that purpose came to terms with Binnie, Deacon & Gourlay.

It also happened that very shortly after the appointment of Binnie, Deacon & Gourlay, Messrs. Scott & Wilson were, on the recommendation of the Institution of Civil Engineers, appointed for the design of all roadwork; in view of their high repute and good general experience in all sides of civil engineering work at home and overseas, it was obviously desirable that this same firm should take

The Dhekelia Project Sketch

on responsibility for *all* civil engineering works within the cantonment, leaving Binnie, Deacon & Gourlay with their more limited responsibilities for which they had originally been briefed before Scott & Wilson had come into the picture at all.

All internal electric wiring, heating, ventilating and air-conditioning is the responsibility of Messrs. Wingfield-Bowles & Partners. Cable & Wireless Ltd. are designing the underground telephone cable layout and the installations inside the automatic telephone exchange, whilst C.E. Cyprus's E. & M. branch under Major Denis McCarthy (now A.D.F.W. (E. & M.) in War Office), in close collaboration with the Electricity Authority of Cyprus, designed the L.V. distribution in the administrative area and the H.V. ring main round the cantonment. For future phases, all L.V. distribution is being designed by Wingfield-Bowles.

2. *Types of Construction*

In general, walls of buildings are of concrete block rendered externally. An appreciation of costs made in the very earliest days by C.E. Cyprus led us to believe that this was a cheaper form of construction than masonry. However, War Office put a somewhat generous interpretation on this specification and designed their buildings with truly massive walls—an inner wall of 9 in., a 3-in. cavity and an outer skin of 6 in., both inner and outer walls being of solid concrete block. Tender prices in the first contract indicated a possible economy here and subsequent designs are being modified to a cavity wall of hollow concrete blocks.

Roofs are either of 30 deg. pitch with Marseilles tiles (favoured in W.O.S.Ds.) or of 14 deg. pitch with factory-made half-round Roman tiles (much favoured by MacDonald). Some of the smaller buildings and annexes to the larger buildings have flat concrete roofs.

Buildings of over two storeys are generally in R.C. framed construction. The first contract contains only one of these, namely the administrative area officers' mess of three storeys. The second contract, however, contains the largest and tallest building of the cantonment, the hospital of five storeys.

Garages, workshops and storesheds of the administrative area are based on the framework of the Indian T.G. shed. (Note "T.G." stands for "temporary garage" and not "tongued and grooved.") (See Photo 4.) Since there were large stocks of this lying idle in Egypt at the end of the war, somebody, economically minded, thought it could be usefully used up in Dhekelia. It has a very simple and light pin-jointed truss of 36 ft. 6 in. span, quick and simple to erect, which can, with rearrangement of the components and introduction of a small range of other parts, be erected in alternative spans of 28ft. 6 in., 24 ft. 4 in. or 19 ft. T.G. sheds are normally clad with C.G.I. but it was realized that this would look a trifle out of place midst the surrounding architectural splendours and so Alister MacDonald was allowed to recommend his own form of cladding; in general he has adopted hollow concrete blocks for side walls and random rubble masonry for end walls. Roofs are in corrugated asbestos cement sheeting (to the "Continental" profile as locally manufactured in Cyprus). MacDonald also made free use of the alternative spans where he thought these would suit the particular purpose of the building better. Thus the R.A.S.C. garages are designed in double 24ft. 4 in. spans, while smaller unit garages are in single 28 ft. 6 in. spans—and there is even one small building (in the petrol depot) where he has found a use for the 19 ft. span. Unfortunately M.E.L.F. only held stocks of the standard 36 ft. 6 in. span and there appeared to be no known stocks anywhere else in the world of the special components required for the other spans. War Office initially assured us that these would be obtained from Ministry of Supply sources and shipped out to Cyprus, but at the last moment—well after the first contract had been signed—we were gently told that supply was entirely our responsibility in Cyprus. An S.O.S. had to be sent to Egypt and Engineer Base Workshops finally produced the goods in the nick of time to prevent any serious delays on the contract.

3. *Roads*

Designs for the roads are being undertaken by Messrs. Scott & Wilson. There are three classifications:—

(*a*) Heavy duty—designed for 20,000 lb. wheel loads, with a pavement consisting of 5-in. sub-base, 7½-in. macadam foundation and 2-in. carpet of hot rolled asphalt. The thickness of sub-base as specified depends on a C.B.R. value of 10 per cent being obtained on the top 18 in. of subgrade. Where this can be exceeded, as is very often the case, the thickness of sub-base can be correspondingly reduced.

(*b*) Medium duty—designed for 7,000 lb. wheel load, consisting of 3-in. sub-base, 5-in. macadam foundation and 1½ in. of premixed bituminized macadam. Again a 10 per cent C.B.R. value for the subgrade is specified.

(*c*) Light duty—for 5,000 lb. wheel loads. The sub-base and foundation for these are as for medium duty roads but they only have a light wearing coat of a cutback bitumen spray with chippings rolled in.

The heavy duty specification is employed only on the main ring road, the central road through the administrative area and inside the R.E.M.E. workshops. Medium duty serves the insides of the other depots and the internal main roads of the system, while light duty is confined to the minor service roads in the married quarters areas and spur roads to living accommodation. The heavy and medium duty specifications are considerably higher than in any other roads found elsewhere in Cyprus; the normal P.W.D. specification for all main trunk roads approximates only to something like the light duty specification.

Widths, too, are ample. The main road along the north side is 33 ft. wide, while the width of other main roads is 22 ft. Widths of other roads vary according to their purposes from 9 to 18 ft.

Finally, there will be a well-thought-out system of footpaths and cycle tracks ensuring direct and simple access between all parts of the cantonment.

4. *Water Supply*

Cyprus is a dry country having virtually no rain from June to October, during which months nearly all rivers dry up. However, Cyprus successfully maintains a growing population of about 500,000 and irrigates throughout the dry summer a large acreage of citrus plantations and other crops requiring a plentiful and continuous supply of water. It does this by means of its extensive underground reserves which lie in well-defined areas over the island. The nearest of these to Dhekelia is in the neighbourhood of the village of Pergamos, three miles to the north-west. However, the reserves in this area are limited and insufficient to meet the full demands of the completed cantonment. But they are accessible at no great cost and so it was decided to develop the Pergamos area, as Phase I of the water supply, to be included in the first contract. Test pumping the area was carried out in the autumn of 1950 and from the test results so obtained it was reckoned there would be a safe and continuous yield of 250,000 gallons per day, sufficient to cover the needs of the administrative area and subsequent constructional uses till the full requirements of the cantonment could be developed from elsewhere. Accordingly the first contract includes a 500,000 gallon ground-level reservoir supplied by four boreholes in the Pergamos area (three in use and one in reserve) automatically controlled by the water level in the reservoir. Submersible pumps are used, each of sufficient capacity to pump right up to the reservoir. Rising mains from the boreholes join a common 8-in. main at a control house, which also includes chlorinating plant. The reservoir itself is about three-quarters of a mile from the north-west corner of the cantonment which it supplies by a 14-in. gravity main. All water mains are in spun iron with bolted flange flexible joints.

There exist ample reserves to meet the full demand of the cantonment, rather farther away but still within reasonable distance, and these will be developed in Phase II together with the necessary additions to the Phase I reservoir.

5. *Drainage*

Dhekelia will boast the first large-scale water-borne sewage scheme to be constructed in Cyprus. The first contract includes a trunk sewer (starting at 6-in. diameter and rising to 15 in.) taking soil and sullage and discharging 150 yards out to sea at the south-west corner of the cantonment boundary. The only treatment given is "comminution", whereby all the solids are cut up very small and discharged out to sea as a "soup". There is no steady set of current in the sea 150 yards from the shore, currents being entirely influenced by the direction of the wind of the moment; however it is confidently believed by the medical authorities that there will be no pollution of the Dhekelia beaches. Should experience unfortunately prove otherwise, there is a suitable site for a full-scale sewage disposal works near the outfall.

High-grade S.G.W. pipes up to British Standard for foul sewers are not manufactured in Cyprus or the Middle East and it was reckoned that the cost of shipping these out from England would be prohibitive and the breakage rate too high. Therefore our civil engineering consultants recommended the use of asbestos cement pipes made by a firm in Italy. In addition to high pressure pipes suitable for water mains, this firm manufactures a range of low-pressure pipes which, it was hoped, would meet the requirements of foul and stormwater drains. However, experience in laying and testing them in the administrative area has shown them to be quite unsuitable for foul sewers, as the joints, however carefully made, cannot be made to stand up to the specified test. The manufacturers have since stated that the joints cannot be guaranteed to stand up against any head at all. We were therefore forced to adopt the expensive and somewhat unsound expedient of completely surrounding all joints in solid concrete before they could be tested. This only applies to branch drains inside the administrative area. We were not so committed for the trunk sewer and there was time to deviate in a change of specification. The same Italian firm makes another kind of asbestos cement pipe, called "Irrigation" pipe, the body of which is nearly the same as for the low-pressure pipes, but with a superior spigot and socketed joint which, they say, can be guaranteed against a 50-ft. head. This appears to be the probable answer, but at the time of writing none have yet reached Cyprus to be tested.*

6. *Electricity*

Electricity is supplied by an underground H.V. main taken direct from the Cyprus power station, which is operated by a nationalized concern called the Electricity Authority of Cyprus (E.A.C.).

There will be a H.V. underground ring main system within the cantonment with eleven substations sited suitably at load centres of the various inhabited zones. L.V. distribution at 230 volts is mostly underground, but to save on cost where this will not seriously affect appearances, it will be taken on overhead line.

* These have later proved entirely successful.

There are no contractors in Cyprus capable of undertaking any large-scale electrical distribution work, particularly at high voltage. All skilled labour used to this form of work is in the permanent employment of E.A.C. or in that of E.A.C's. own British contractor, British Insulated Callender's Cables Ltd. (and E.A.C. has, under the terms of its contract, a monopolistic right on the services of this company in Cyprus). The War Office therefore agreed, with considerable reluctance, that E.A.C. should undertake the laying of all H.V. mains and installation of transformers, etc., on behalf of the War Department as an agency service, being paid cost of materials and labour only plus an agreed percentage for overheads.

In the first contract, E.A.C. are responsible for both the low and high voltage work; War Office only agreed to this owing to the super priority accorded to the first contract in the early planning days.

7. *Heating*

The winters in Cyprus, especially near the coast, can at times be unpleasantly cold and wet, and some form of space heating in living accommodation is essential. This fact is freely granted by War Office, but they fail to take quite such a lenient view over offices and other places of daily labour; these, they say, if they require heating at all, must be satisfied with what Ordnance can supply in the way of oil stoves. However, for barrack blocks and messes, low-pressure hot water radiators have the official blessing. Facts and figures were produced by the heating specialists in the early days to prove that district heating would be the cheapest method of achieving this. But since, in general, unit locations are fairly widely scattered over the cantonment, it was fairly obvious that one large district heating scheme would not be practicable. So it was decided that each separate major unit (or any pair of units that happened to be sited conveniently close together) should be served by its own separate heating scheme, each with its own boiler house and system of high pressure steam mains, supplying heat to calorifiers in the different barrack blocks, messes, etc. Such a scheme was planned in detail for the administrative area by our E. & M. consultants, Messrs. Wingfield-Bowles & Partners. Then came the financial blitz in the autumn of 1951 when the capital cost of the cantonment had to be drastically reduced before final approval could be given. District heating, which had always been slightly vulnerable as a luxury, was the first obvious cut to be made. It was also ruled that space heating should only be allowed for day living accommodation and not in bedrooms and barrack rooms—which, of course, puts the economics of district heating in a very different light. So back we went to individual boiler rooms for each building, and the whole concept of district heating, revolutionary as far as Cyprus is concerned, became a glorious "might-have-been".

Photo 1.—Part of the Dhekelia Cantonment.

The Dhekelia Project 1

Photo 2.—General Panorama of Administrative area. Taken in March 1954.

Photo 3.—Barrack Blocks. Taken in November 1953.

Photo 4.—Framework of a double 36 ft. 6 in. T.G. Shed to be used as a R.E.M.E. workshop.

The Dhekelia Project 2 ,3, 4

Photo 5.—R. and F. Mess (W.O. Standard Design). Taken in January, 1954.

Photo 6.—D.C.R.E.'s Office. Taken in November, 1953. A typical example of A. MacDonald's design for offices.

Ideas for the Future

The rate of progress of any major project in Cyprus is controlled by two limiting factors—the availability of skilled labour and the economy of the island. At first it looked as if the first of these would be the overriding factor, but with the post-war building boom in Cyprus and the attractive rates of pay in the skilled trades, more and more Cypriots are learning a trade and in a year or two's time there should be no shortage, anyway, of masons, carpenters, plasterers and painters; the situation may become acute with electricians and plumbers, but it is too early to say yet. However, the Cyprus Government view with considerable concern the prospect of the War Department pouring into the island, in the form of builders' wages, large quantities of money every year. The money thus introduced is unlikely to be put into savings, but will be spent with the small trader, who will himself join in the spending spree; it will therefore have the maximum inflationary effect and at a level impossible to get at by direct taxation, which, the economists say, is the easiest method to combat inflation. This fact alone sets an upper limit to the rate of progress of the major W.D. projects in Cyprus which, at Dhekelia, is now set at £2 million per year (total value of work, including cost of imported stores). Bearing this figure in mind, War Office have phased the whole project through in a number of isolated contracts, some large ones of a million pounds and over, these generally being for unit zones and married quarter estates, to be let in U.K., and other smaller ones for the more isolated buildings, such as the O.Rs'. Garrison Club, to be let locally.

The next contract to start will be the B.M.H. and its three associated messes, medical officers, W.Os. and sergeants, and Q.A.R.A.N.C. This went out to tender at the beginning of October, 1953, and work was expected to start in April, 1954. It is a development being watched with the keenest interest by all service men in Cyprus, as the existing B.M.H. is the old war-time hutted hospital in Nicosia, a most dismal place to be sick in and an even more dismal place for the medical staff who work in it; it is also a perpetual headache for the C.R.E. who has to maintain it, as many of the roofs are unsafe and there are no damp-proof courses to the walls. The amount of money that is being continually poured into it is a constant and heavy drain on M.E.L.F. Part III resources.

The new hospital at Dhekelia will be Alister MacDonald's *pièce de résistance* (see perspective Sketch 3 between pages 12 and 13). Based on the most up-to-date principles of hospital design, it is magnificently sited from where it commands the whole sweep of Larnaca Bay with the entire cantonment spread out in front of it and below it. The main block comprises the administrative offices and eight wards looking out over the sea, each with large and wide balconies; behind the main block there is a double storeyed wing for out-patients, maternity, surgical and the various other specialist departments. There is a 100,000-gal. water tank on the roof, which has been made a feature of the elevation; this is required since the main reservoir is not quite high enough to supply the upper storeys of the hospital, and water will therefore have to be pumped and additional local storage provided. The whole hospital will cost about £750,000 and will be completed, it is hoped, by October, 1956.

This contract will be shortly followed by the first batch of married quarters, an estate sited immediately to the west of the administrative area. This third contract, which also includes a primary school and teachers' hostel, is at the time of writing in a fairly advanced state of preparation. For the remainder of the project the War Office have worked out a carefully phased programme of contracts, but those responsible are realists enough to appreciate that this only represents the ideas of to-day. By to-morrow a different set of circumstances may necessitate a completely different programme.

However, to anyone who is aspiring to what must be the plum of all C.R.E. appointments, I may say that the project will be running along on full steam until 1959 at least.

Lessons

I made a promise in the Introduction to this narrative to try and summarize the lessons that have been learnt to date, in so far as they are generally applicable to the planning of a major project of this nature. I have had the good fortune to be associated with the engineer staff planning of the Dhekelia Project from almost its earliest conception to the time when it has become a going and growing concern and I have thereby unconsciously absorbed certain basic principles after many months of struggling and arguing on the files. I therefore feel that the most suitable and simplest way of dealing with the lessons learnt is to expound and enlarge on these principles, drawing where appropriate on our Dhekelia experiences. Principles are, by their nature, generalizations and generalizations are notoriously dangerous things to indulge in. But I can only say in self-justification that the four main principles that I shall now rashly put forward were all to a greater or lesser degree broken in planning the Dhekelia Project with results that were only too clearly on the debit side of the account. I will certainly not be rash enough to suggest that these Four Principles of Planning (to give them the dignity of capitals) are inclusive of all lessons so far learnt. Doubtless the foregoing narrative has implied several others which might be fairly stated, and there are certainly many others buried in the welter of detail which I have not had the courage to plunge into. But these are the Big Four as I see them and, anyway, four is quite enough for me to try and put across.

1. *The planning of any project, big or small, cannot be rushed*

We all know that the Sappers have a well-deserved reputation for achieving the impossible—but there are degrees of impossibility—and it is only right that we should be humble and confess to our limitations; but confessing is not enough in itself—we must also impress on others what these limitations are. It is wrong, utterly wrong, for any Sapper to promise his opposite number on the "Q" staff an over-optimistic date for the start of any project. Engineer planning on any scale, large or small, is a slow and deliberate process and any effort to speed up its natural rate of evolution will only cause mistakes, which will certainly cost money and very likely time as well. This applies to all Sapper tasks, whether in field engineering or on works services; the only difference is that in the former much of the planning has already been done in the various M.E. volumes and there only remains the application of the standard "book" project to the conditions found on the ground. But on works services, all planning is *ad hoc* and each project must be worked through individually from start to finish; there are also the frustrations of the peace procedure to be tackled, with its presentations, estimates and all the rest of the red tape business (although I am not making any heretical suggestions that these are unnecessary), all of which amount to a very appreciable amount of planning effort.

Purely as a matter of my own personal opinion, based on my own experience and observation in Cyprus (where there is an S.Q.S. on the C.E's. staff), I would say that the time taken to carry through the engineer planning of an average works project overseas would be very approximately as follows:—

Size of project	*Planning time in months*
£10,000–£50,000	4
£50,000–£100,000	6
£100,000–£250,000	8
£250,000–£1,000,000	12
£1,000,000–£2,000,000	18

"Planning time" is taken as the date when the "Q" brief is received in its final form with no subsequent alterations, or the date of receipt of Approval-in-Principle (whichever is the later), to the date when work actually starts on the ground; the "average project" is one that includes a reasonable number of repetitions, standard designs, etc., and in which there are no difficult engineering problems to be surmounted. The above table also assumes an adequacy of drawing office and quantity surveyors' staff and no interruptions; it also assumes, of course, that Approval-in-Detail is forthcoming in reasonable time after submission of A.F.M1428. Thus these times are reasonable *minimum* times. I would also like to emphasize the definition of the "average project". Each project must be judged by itself against this definition. Thus the Dhekelia second contract, which comprises the B.M.H., three special messes of non-standard design and a good proportion of roads and services, is wholly specialized with virtually no repetitions and so, although only of the order of £1 million, it will have taken nearly two years to plan to completion.

If, therefore, we are told by the "Q" staff that work on a given project of, say, £200,000 must be started in six months' time, it is our inescapable duty to say "Sorry, it can't be done". We are not being clever and efficient and ripe for promotion if we say "Right, old boy, leave it to me" and then go and badger our long-suffering architects, draughtsmen and quantity surveyors to achieve the impossible. Mistakes will inevitably be made, and these mistakes will just as inevitably cost money to put right, for you may be sure they will not be discovered till the wretched C.R.E. responsible for executing the work comes across them in actual construction, if then—instead of them being discovered in the course of the normal careful checking of drawings, etc., which *must* be part of any proper planning. What is more, they will probably take time to put right and the net result may well be that the proper completion of the project is considerably later than if due time had been allowed for the planning. Or, to extend an old proverb, "More haste, less speed and more waste".

2. *The "Q" brief must be firm and final before planning starts—there must be no "second thoughts".*

This is a hard principle for us Sappers to apply, if not an impossible one, since it implies that we have the power to control the thoughts and deeds of our "Q" friends on the other side of the corridor. But once we have received the brief (and badgered "Q" to supply all the details which will inevitably be found missing), it is once again our bounden duty to say with all the force of our personality "Right. Let there be no change in this brief and we will produce the goods. But be warned here and now that if you try to make any appreciable alteration to the scope of any part of this project, you will be throwing a spanner into the works which will cause delays and cost money." Of course, it is unlikely that our words will be heeded and it will be almost certain that in any major project, the spanner will be well and truly deposited, by someone in high authority, where it can do most damage. But we will have done our best and if our warning has not had any effect, we have at least provided ourselves with a suitable umbrella against subsequent delays and expenses.

It is a prevalent fault amongst the staff to be too meticulous about details. They want everything to be tailor-made to the last synopsis foot super, to fit a lot of establishment figures that "G" have worked out for them; they are too inclined to lose sight of the fact that units hardly ever work to their correct establishments. Also our buildings are designed and built (we hope) to last for one hundred years at least, and no establishment has been known to remain constant for more than three years. So let us give the units something now, into which they can be reasonably expected to accommodate themselves somehow, instead of trying to alter things during the planning or (far worse) constructional stages to fit in with any and every subtle change in their numbers and functions as they occur. In the oft-repeated words of our former Chief Engineer, Brigadier Pritchard—"Do not let the best become the enemy of the good."

3. *User agreement to layouts must be obtained at all levels right from the start*

In Phase I of the Dhekelia Project, C.E. Cyprus provided briefs for all specialized buildings and in every case obtained user agreement to the sketch plans before working drawings were allowed to proceed. For some reason this did not apply quite so rigidly to the layouts of the depots, etc. Briefing for these was supplied to Alister MacDonald by War Office, who also provided the ultimate approval. C.E. Cyprus was only consulted occasionally and by chance and the first we knew of the final layout for some of the depots was when we saw them in the first contract working drawings. The fault, of course, was ours for failing to see the wood for the trees, but the result was that when the various user services began criticizing the layouts in the summer of 1953 (as described in Part I), we were unable to provide the most effective answer, which was to produce a plan of the layout actually agreed and signed by the complainant's predecessor in office. Such criticisms are almost bound to occur in any similar project and may occur at any level from District to War Office. This is especially so where a long time is allowed to elapse between the early planning and execution of the work, as with the administrative area, during which time individuals with their own particular ideas on the subject are bound to change. So I say, prepare for these criticisms in advance by insisting that the consultant (if one is employed on layouts) sends out to you three copies of the layout plan (at 1/500 or the largest convenient scale) as soon as this has received War Office blessing; get signatures on the plans from "Q", the user service and, if applicable, D.A.D.A.H.; leave one copy thus signed with the user, retain one yourself and send the third to your Command H.Q., asking that they too obtain a similar collection of autographs. You or your successor are then in an impregnable position to foil future criticism and the amount of heart searchings, file searchings and time-wasting correspondence that will thereby be saved will be out of all proportion to the small amount of effort spent on these simple precautions.

Where user services are not involved in the layout, such as with married quarter estates, town centre or other communal amenities, it is really entirely a matter between you and your consultant, with "Q" and your district commander indirectly affected—but these latter should be content to be guided by your advice.

Of course, in getting local user agreement to the layouts, you have a very strong card to play by pointing out that the said layouts have already received War Office approval and if the users don't like it they will have to take the matter up on their own service channels. This should be sufficient to silence any possible protests and win an easy signature.

4. *Everything must be completely ready on the ground by the time work on the project starts, despite any possible financial risks thereby entailed.*

The word "everything" in this statement is all embracing and includes the following more important details:—

(*a*) The executive organization must be complete in all its essential appointments. It will be almost inevitable that any major project developed in an overseas station will be well outside the capacity of the existing works service organization; therefore, as with Dhekelia, a special establishment will have to be formed to deal with it. This establishment must also have its offices and living accommodatiou (if on an isolated site) all ready, which may itself involve a quite appreciable amount of preliminary expenditure. The Dhekelia first contract got off to a bad start since the C.R.E. and other important appointments were not filled for several weeks after the site had been handed over to the contractor. But shortage of staff was not the only trouble; lack of sufficient typewriters and, more important still, survey equipment was a serious embarrassment to the C.R.E. in the early months and he was largely dependent on the goodwill of the contractor to help him out. However, the situation was better regarding the C.R.E's offices and living accommodation as, for both, use could be made without much trouble and expense of existing huts in the old war-time Dhekelia camp. But for the Episkopi project, which is sited 14 miles from Limassol and entirely isolated, a complete hutted camp has had to be erected for the C.R.E. to live and work in at a cost of several thousand pounds.

(*b*) Drawings, bills of quantity and particular specifications must be available for study by the C.R.E's. staff before work on any particular contract in the project is started. These will enable the C.R.E. to put in his stores demands for items of W.D. supply in good time, will enable him to work out the degree of supervisory control required and thereby distribute his resources to the best advantage, and also foresee what constructional snags there are likely to be. A resourceful C.R.E., with intimate knowledge of site conditions, should always be able to suggest a few modifications to the designs which may improve both time and cost; if he has the opportunity of making these suggestions to the responsible consultant in good time, before he is rushed into making a spot decision by the progress of the work, sounder decisions will be reached and relations with the consultant will remain happy. As we have seen in the administrative area contract, drawings arrived in dribs and drabs throughout the first six months or so. Such drawings as were received at the start of the contract could not be effectively studied since there was virtually no one available to study them. In many cases, site conditions forced the C.R.E. to make decisions on the spot involving quite radical alterations to the designs and the responsible consultants could only be informed afterwards. They accepted with surprisingly good grace some *faits accomplis* which they would have much preferred to have considered and discussed a bit first, and very possibly improved on, which is only natural; and of course we would have preferred it thus too, since the works officer has not the specialized knowledge of the consultant and we realize that spot decisions may not be the best and may even be unsound engineering practice. However, with virtually no opportunity to study the drawings before the work was put in hand and with the contractor pressing for decisions, there was no other way if the contract was not to be held up.

(*c*) All testing apparatus must be installed and ready for use by the time work starts. This is a very important point for overseas projects, especially in the more under-developed colonies and is likely to be overlooked by those accustomed to conditions in Home Commands. The natural standard of workmanship in concrete of the local labour is likely to be low, making it all the more necessary for strict control and frequent testing with test cubes; but there is also unlikely to be proper concrete testing facilities available in the colony. At any rate, this state is certainly applicable to Cyprus. Part of the preliminary works to the project for which A.-in-P. was given as early as September, 1950, and A.-in-D. in 1951 (with later revisions in 1952) was for a fully equipped test laboratory, including a concrete-testing machine. On receipt of A.-in-D. a demand was put in for the necessary stores; but such was the general atmosphere of uncertainty over the future of the project prevailing at the time, that War Office ruled that orders could not be placed on the trade for the necessary equipment until the first contract had actually been signed. When the Ministry of Supply was eventually permitted to deal with the orders in October, 1952, it was found that there was a fifteen months' delay in the supply of concrete testing machinery. The result is that the C.R.E. is still, at the time of writing, operating without any proper control over the standard of concrete. Some specimen cubes were sent to the War Office for testing in 1953, which we fondly hoped were fairly representative, and the results were most encouraging, but no one can be really happy about the situation until the test machinery has arrived. All this is because someone was unwilling to take a small risk involving the expenditure of a few hundred pounds while the fate of the project as a whole remained in the balance. The possible loss to the War Department through inferior workmanship is incalculable. Further comment is hardly needed.

(*d*) The supply of constructional water must be assured. This is a very important consideration in sub-tropical countries with little rainfall and looking for a suitable source may require quite a bit of research and expenditure. Happily this point was well covered in the administrative area contract.

(*e*) Adequate resources of sand and aggregate must be found in advance and their suitability for good concrete assured. This may well involve preliminary investigations lasting several months and the results of these investigations must be placed at the disposal of all tendering contractors.

These points all emphasize one clear fact. If everything is to be ready by the time work starts on the project, a lot of money must already have been spent. If, for any reason, the fate of the project is hanging in the balance till the last moment, it is a false economy of a high order to withhold money from these preliminary works. The amount involved will, after all, be only a very small proportion of the total value of the project and the possible loss to the taxpayer insignificant. If things do start suddenly and all is not ready, the money thereby wasted will certainly be very much greater. We fell short of the ideal at Dhekelia in three respects: firstly, the executive staff with its necessary equipment was very incomplete, secondly, drawings, etc. were not ready and thirdly, there was no concrete testing apparatus. There is no doubt at all that the first contract has suffered in consequence. It all boils down to spoiling the ship for a ha'porth of tar.

SUMMARY

A. Planning cannot be rushed.	"More haste, less speed and more waste."
B. The "Q" brief must be firm and final.	"Don't let the best become the enemy of the good."
C. User agreement to layouts must be obtained at all levels.	"A stitch in time saves nine."
D. Everything must be ready on the ground for the start of work, despite possible financial risks.	"Don't spoil the ship for a ha'porth of tar."

APPENDIX

Holders of main engineer appointments in Cyprus connected with the project (up to December, 1953).

Chief Engineer

Colonel G. A. T. Pritchard, C.B.E.	May, 1950–November, 1951
Colonel B. E. Whitman (became Brigadier December, 1952)	December, 1951–March, 1954

S.Q.S.

Lieut.-Colonel R. T. Foreman, F.R.I.C.S.	April, 1951–February, 1952
Lieut.-Colonel F. N. Croft, F.R.I.C.S.	February, 1952–May, 1952
Lieut.-Colonel J. F. McKenna, F.R.I.C.S.	April, 1952–January, 1954

S.O.II (Plans)

Major P. C. Grant	August, 1950–January, 1951
Major J. D. Edgar, A.M.I.C.E. (appointment up graded to S.O. I in December, 1952)	January, 1951–December, 1953
Lieut.-Colonel R. D. Hatcher, M.B.E.	December, 1953

S.O. II (Wks.)

Major H. W. H. Rose	July, 1950

S.O. II (E. & M.)

Major D. W. C. McCarthy, M.B.E.	July, 1950–March, 1953
Major J. P. Ewart, A.M.I.E.E.	February, 1953

S.O. II (Stores)

Mr. R. A. Wellings	January, 1951

S.O. III (P. & A.)

Captain L. H. Dawson	August, 1950

C.R.E. Dhekelia

Lieut.-Colonel C. E. Warth, A.M.I.C.E.	December, 1952

141 *Ind. D.C.R.E.*

Major L. D. Halestrap	July, 1950–December, 1952

(appointment ceased on establishment of C.R.E. Dhekelia, Major Halestrap then became A.C.R.E.)

No. 1 *D.C.R.E.*

Major M. J. Baber	December, 1952–August, 1953
Major W. J. W. Crossby	August, 1953

No. 2 *D.C.R.E.*

Major A. D. Henderson	September, 1952

GAS TURBINES TODAY

By Major A. A. T. Hiscock, B.Sc., R.E.

General Outline

AN article entitled "Possible Military Applications of the Gas Turbine" by Lieut.-Colonel A. L. Hicks, O.B.E., R.E., appeared in the December, 1950, issue of the *Journal.*

Lieut.-Colonel Hicks outlined the basic principles of gas turbines and discussed a number of possible military applications. In this paper I propose to review the state of gas turbine development to-day and to show the progress which has been made in the past four years. It is not possible to describe in detail all the gas turbines in operation or under development and so I have indicated the extent of the work in progress, including details of a few representative turbines of particular Sapper interest.

Gas turbines which are at present emerging from the development to the application stage, apart from aircraft turbines, fall into three main categories:—

1. Static and transportable turbines for electric generation and water pumping up to 30,000 kW.

2. Small turbines for automotive use and emergency water pumping, etc.

3. Medium-sized turbines for marine and locomotive applications.

Of these, those used in static installations may use a variety of fuels including oil, pulverized peat, coal, and industrial gases and they may be open or closed cycle. Although there are a few exceptions, the remainder are generally confined to the use of liquid hydrocarbon fuels and are of the open cycle variety.

The thermal efficiencies obtained in practice have been something below that expected from theoretical considerations and they have varied from about 32 per cent, which is claimed for certain large static installations with heat exchangers, to well under 10 per cent for certain small engines, particularly those for automotive or locomotive use.

Before proceeding to details it is interesting to note that four countries appear to be in the lead as regards over-all gas turbine development, namely, the United Kingdom, France, Switzerland and the U.S.A., although Canada, Denmark, Holland, Japan, Sweden, Italy and Russia are also actively engaged in development work.

Fuels

The low thermal efficiencies obtained in practice have led to high fuel consumption in many applications. A gas turbine using liquid distillate fuels of the same type as the diesel engine cannot hope to compete with it, therefore, on purely economic grounds and the peculiar advantages of the turbine, including quick starting and a low specific weight are not always sufficient to tip the scales in its favour.

The search for methods of utilizing low cost residual oils, peat and pulverized coal has therefore continued, vast sums of money being expended in these directions, with varied success. At the same time it must be remembered that much progress has been made with diesel engines and they too can now employ much heavier residual fuels than was formerly the case.

The main difficulty with the use of heavy fuels has arisen from the corrosive nature of some of the combustion products, notably vanadium pentoxide. This melts at 600°C. and in the molten condition has had disastrous effects on turbine blading.

A limit has thus been imposed on the temperatures employed when vanadium bearing residual fuels have been used, and unacceptably low thermal efficiencies have often resulted. There has been some success in overcoming this and similar difficulties.

Most of the vanadium can be removed from the oil by precipitation, and sodium, which is also objectionable, can be removed by centrifuging. Alternatively an additive can be put into the oil immediately before combustion and certain silica compounds have shown very promising results. The main problem at the moment is the production of a cheap additive in satisfactory form which does not bring other problems in its wake.

The use of pulverized coal has naturally received much attention and one of the important advantages which may follow is the use of much low-grade coal, which is at present unusable. Both open and closed cycle turbines are being developed for coal utilization, but it would appear that the closed cycle turbine may be at an advantage in this case, at any rate for large static installations.

John Brown, working in collaboration with Escher-Wyss, have done much work on closed cycle coal-burning turbines and consider that their 1,000 kW. coal-fuel gas turbo-alternator under erection at Clydebank will show that the most important problems have been solved.

One of the chief difficulties with the open cycle has been the separation of the ash before passing the combustion products through the turbine and over $4 million have been expended by Bituminous Coal Research Inc. in the U.S.A. to develop an open cycle coal-burning gas turbine locomotive. So far this has not passed the development stage owing largely to these ash separation difficulties, but figures published indicate a thermal efficiency, in the case of a 4,000 h.p. Allis Chalmers machine, with heat exchanger, of 15–20 per cent. Recent information is that the ash separation difficulties now seem likely to be overcome more successfully than seemed possible a year ago.

The use of peat as a fuel has been under active consideration in Great Britain for some years with the object of utilizing the vast deposits of peat in Scotland and Ireland and which have, at present, little economic value. This has led to successful trials with a Ruston and Hornsby 3 C.T. 1,000 h.p. turbine which are still proceeding. The first peat-burning power station will be built at Altnabreac, Caithness.

Gaseous fuels are of great importance in gas turbine applications and there are many installations which make use of gases. These range from gasified coal, through natural gas from oilfields to process waste and sewage gas.

Metallurgy and Blade Cooling

As the useful output of a gas turbine is related directly to the absolute temperature of the hot gas supplied to it, the importance of high gas temperatures is clear. Unfortunately the combination of heat and stress present in turbine blades has limited the temperatures and efficiencies which could otherwise be obtained. The development of alloys which can resist these temperatures and stresses has been the subject of intense research for a number of years and remarkable results have been obtained. One of the chief difficulties has been the "creep" and failure of metals under their service conditions, which has set limits to the time for which turbine blading can be used under high temperature and stress. For instance a certain alloy at 650°C. stressed at 80,000 p.s.i. will break after 100 hours but will last 1,000 hours at 68,000 p.s.i. At 815°C. the corresponding figures fall to 28,000 p.s.i. and 18,000 p.s.i.

Many suitable alloys contain high proportions of strategic materials such as chromium, nickel, cobalt, molybdenum, tungsten and titanium; almost all of those used contain carbon, chromium, nickel and iron. The important British "Nimonic" group of alloys contains nickel and chromium. "Nimonic 95", the latest in the range, has a 100-hour stress to rupture value of 20,000 p.s.i. at 870°C.

A certain amount of blade cooling by air has been carried out in almost all turbines and many ingenious devices have been introduced including hollow and porous blades. Water cooling has, so far, failed to become a practical proposition.

Attention has naturally been turned to unorthodox materials for blades, including ceramic and metal mixtures, the chief difficulty lying not so much with lack of strength as with susceptibility to thermal shock. Ceramic blades have not yet progressed beyond the development stage.

HEAT EXCHANGERS

The object of the heat exchanger is of course to raise the efficiency by using part of the waste heat in the exhaust gases to heat the air which has been compressed. This was not discussed very fully in Lieut.-Colonel Hick's paper, and a short general description is therefore given below.

The simplest form of heat exchanger is the conduction or recuperative type in which a metallic surface is exposed to hot exhaust gases on one side and relatively cool compressed air on the other. There is no difficulty in making a heat exchanger of this type provided weight and space are unimportant, and a number of static turbines in operation have conduction type heat exchangers. These can and do vary in type and layout, ranging from the contra-flow shell and tube exchanger to various plate and corrugated foil types which reduce the bulk considerably. One of the most difficult problems is the fouling of the passageways due to oil, dirt, soot and combustion products. These reduce the heat transfer rate and also cause considerable increase in pressure loss.

The regenerative or capacity type of heat exchanger involves placing a heat capacity alternately in the hot and cold streams of gas and the two possible methods involve either rotating a drum or disc consisting of a matrix of small diameter passages, or switching the hot and cold gas flow to pass through alternate sides of a fixed regenerator. In this case there is less difficulty from fouling owing to the action of the clean compressed air. In addition, construction with smaller passages is easier, as the passages do not have to be collected into separate headers for hot and cold gases. The greatest difficulty arises from the necessity, in the rotating type, for a seal at the face of the matrix. The fixed type similarly has a sealing problem with respect to the valves. Much progress has been made, however, with regenerative, particularly rotating regenerative exchangers, the small sizes which have proved possible being a great attraction.

Despite the obvious advantages of utilizing a higher proportion of heat by means of heat exchangers, experience has shown that it is not always economic to use them and it is now apparent that in many applications heat exchangers will not be fitted. For small sized automotive turbines in particular the exchanger must be both small and cheap. The only automotive turbine so far exhibited with a heat exchanger is that in the Chrysler 120 b.h.p. car, which is understood to have one of the flat plate recuperative type, although the Austin Motor Co. have stated that their 125 b.h.p. gas turbined Sheerline contains a cross flow recuperative exchanger.

Much effort has been put into heat exchanger development. The National Gas Turbine Establishment were engaged on development of a rotary regenerative disc type from 1946 until 1952, when work ceased owing to the solving of the major problems. Commercial development is proceeding and it is known for instance that the Austin, Rover and Turbion companies are very active in heat exchanger work.

Static and Transportable Turbines

As already outlined, the static turbine may employ a variety of fuels and either the open or closed cycle. The permutations and combinations of cycle layout are almost bewildering and it is perhaps in this field of static turbines that the biggest lesson has been learned, namely that complex designs are likely to prove troublesome and disappointing.

Simple turbines are proving themselves more reliable even in the largest sizes.

This is reflected in the two largest gas turbines under construction in the United Kingdom, which are each of 20,000 kW., manufactured by English Electric. They are of the open cycle type with two-stage compression and separate power turbine driving the alternator. These turbines are by no means the largest installed, the Swiss firm of Brown-Boveri having installed a 27,000 kW. set at Beznau in 1948–9. This set, together with a 13,000 kW. gas turbine generator already installed, forms a 40 mW. winter peak load station. The United States do not in this instance even approach the largest, the biggest in the U.S.A. being the 15,000 kW. set under construction by Westinghouse for natural gas operation. This set is remarkable for its compactness and light weight, however, the whole installation measuring 80 by 45 by 18 feet and weighing only 300 tons.

It would be tedious to relate details of all the turbines at present installed and under construction. There are a number of sets of 20,000, 15,000, 12,000 and 10,000 kW. already installed and operating in Great Britain and Europe. In America, apart from the 15,000 kW. set already mentioned, nothing over 5,000 kW. has so far been manufactured.

Inevitably there will always be much R.E. interest in transportable turbines, particularly for electric power generation, and many suitable sets have been made in the range 6,000 kW. and below. The largest known to the author are the two 6,200 kW. sets under construction by Brown-Boveri for Mexico. A 5,000 kW. Westinghouse gas turbo-generator has been ordered by the U.S. Army for installation in a railway wagon and another U.S. Army project is the 1,800 b.h.p. turbine, also Westinghouse, which is to be lorry mounted in order to drive air compressors. The design of this turbine, however, appears to be rather outdated. The U.S. Navy have also shown interest in rail transportable generators, and have ordered a 4,500 kW. Clark gas turbo-generator to be contained in an 85 ft. long railway wagon.

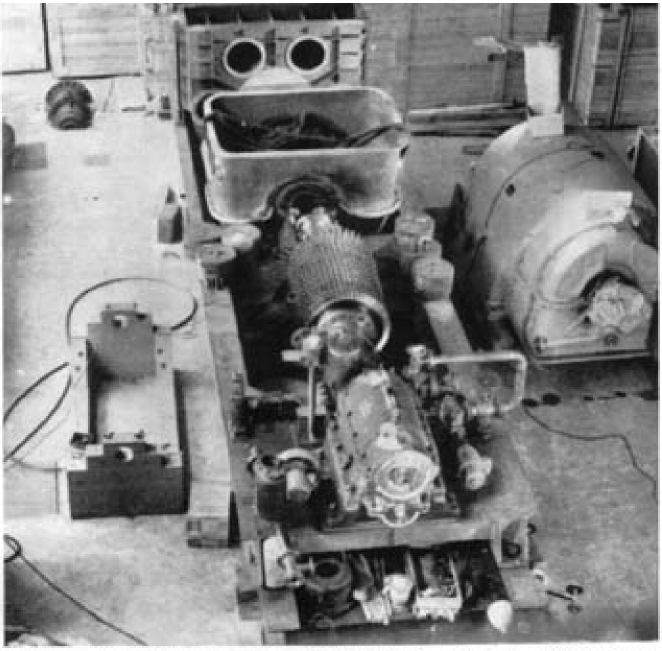


Photo 1.—Svenska rail-borne plant.—Assembly of the set. The 14 stage axial compressor is prominent in the centre of the photograph.

By courtesy of Svenska Turbinfabrics Aktiebolaget Ljungstrom.

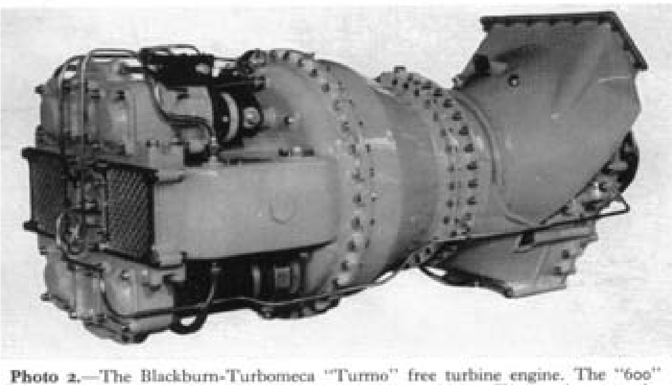


Photo 2.—The Blackburn-Turbomeca "Turmo" free turbine engine. The "600" develops 450 b.h.p. and has a designed life of 2,000 hours. Two engines may be coupled together, with a common gearbox, to give 900 b.h.p.

By courtesy of Blackburn & General Aircraft Ltd.

Gas Turbines Today 1 , 2

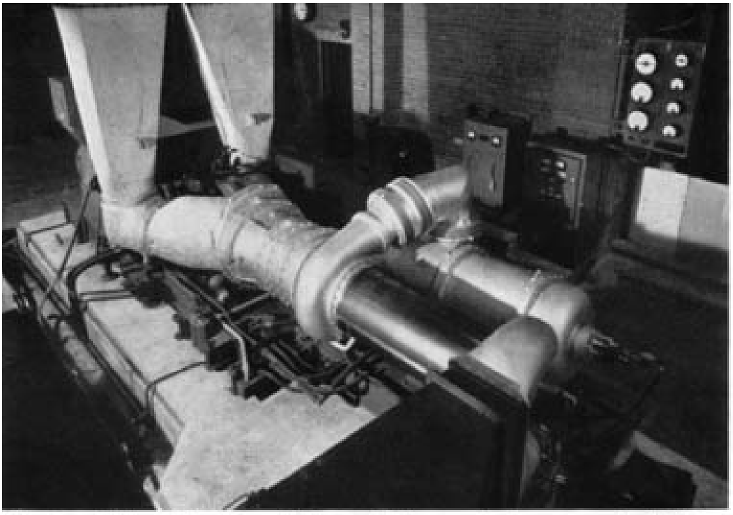


Photo 3.—A view of the Ruston T.A. 1,000 kW. gas turbo-alternator as installed in a R.A.F. camp. No foundations in the accepted sense are required. Adjustable screw-acks enable the power unit to be operated on surfaces which are not completely flat.

By courtesy of Ruston & Hornsby Ltd.

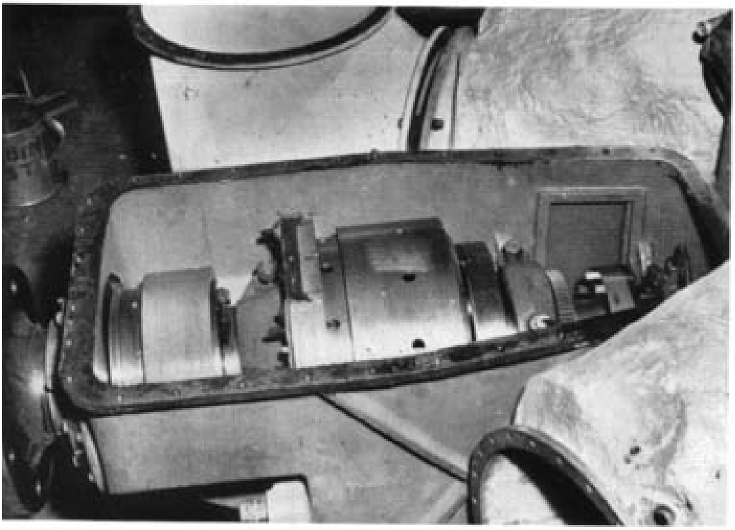


Photo 4.—The Allen-Stoechicht epicyclic reduction gear, with top removed.

By courtesy of Ruston & Hornsby Ltd.

Gas Turbines Today 3 , 4

There is already in existence a very interesting Swedish rail-borne generating plant of 2,400 kW. This is made by Svenska Turbinfabrics Aktiebolaget Ljungstrom, who are well known for their work on steam turbines. The complete rail-mounted installation weighs 90 tons and is 67 ft. in over-all length. The machinery weighs 38 tons of the total. Photo No. 1 shows the assembly of the set, the five stage turbine and the fourteen stage axial compressor, and while there is nothing very unusual about the design of these, they are included to show the types of components which will be encountered in medium sized installations. Although not in the photographs a heat exchanger is included in the circuit. It is situated above the combustion chambers and turbine, is of the cross flow recuperative type and has a thermal ratio of 50 per cent. The over-all efficiency at the generator terminals is 20 per cent at full load and 14 per cent at half load, the full load fuel consumption (gas oil) being .90 lb. per kW./hour. Starting is by means of a 90-h.p. diesel engine.

There are, of course, a number of British Turbines which could be used for this or similar purposes, but one of the most interesting and successful is the Ruston & Hornsby T.A. 750/1,000 kW. set, of which three have been ordered by the Air Ministry. At least twenty-five of these sets have so far been ordered and a number have already been installed, much useful experience having been gained. The T.A. turbine is simple, robust and flexible in layout and would undoubtedly lend itself to a number of military applications. It is guaranteed to give 900 kW. at an ambient temperature of 65° F. at a thermal efficiency of 15.9 per cent. With a heat exchanger of 75 per cent thermal ratio it is guaranteed to give 750 kW. at 22.5 per cent under the same ambient conditions.

The manufacturer's fuel consumption curve for the T.A. turbine is reproduced on page 29. This illustrates clearly how the specific fuel consumption of a turbine rises at part load. The turbine comprises a thirteen stage axial compressor driven by a 2-stage compressor turbine, a completely separate 2-stage power turbine assembly driving the alternator or other driven machine, and a single combustion chamber usually of the type which is shown in Photo No. 3. The compressor speed is about 11,500 r.p.m. without heat exchanger, and the power turbine speed 6,000 r.p.m. An Allen-Stoechict epicyclic gearbox is used, the standard gearcase being capable of housing a series of geartrains giving different output speeds, including the synchronous 50-cycle alternator speed of 1,500 r.p.m. A general view of the gearbox is shown in Photo No. 4.

The set, without heat exchanger weighs about 15 tons and under normal conditions would have a life of about 100,000 hours.

There is little doubt that among the most significant applications of medium and large gas turbines are those involving the utilization of waste heat, and it is in this field that the really economic use of gas turbines should make the most rapid progress.

There is already a 700 kW. John Brown turbine at Coventry which uses waste heat, and eight Ruston turbines are to be erected at Beckton Sewage works for the L.C.C. These will use sewage gas as fuel and will produce compressed air and electricity, hot water being produced from the exhaust gases.

Small Turbines

I have taken this category to include those up to about 500 b.h.p. and it is pleasing to record that the first really successful small turbine was that produced by the Rover Company in 1950. The Americans were not far behind, for the Boeing Airplane Company produced a gas turbine powered lorry in the same year. This however was powered by a turbine which was a modification of an aircraft jet engine. The Rover turbine, developing 100 b.h.p. was a completely new design.

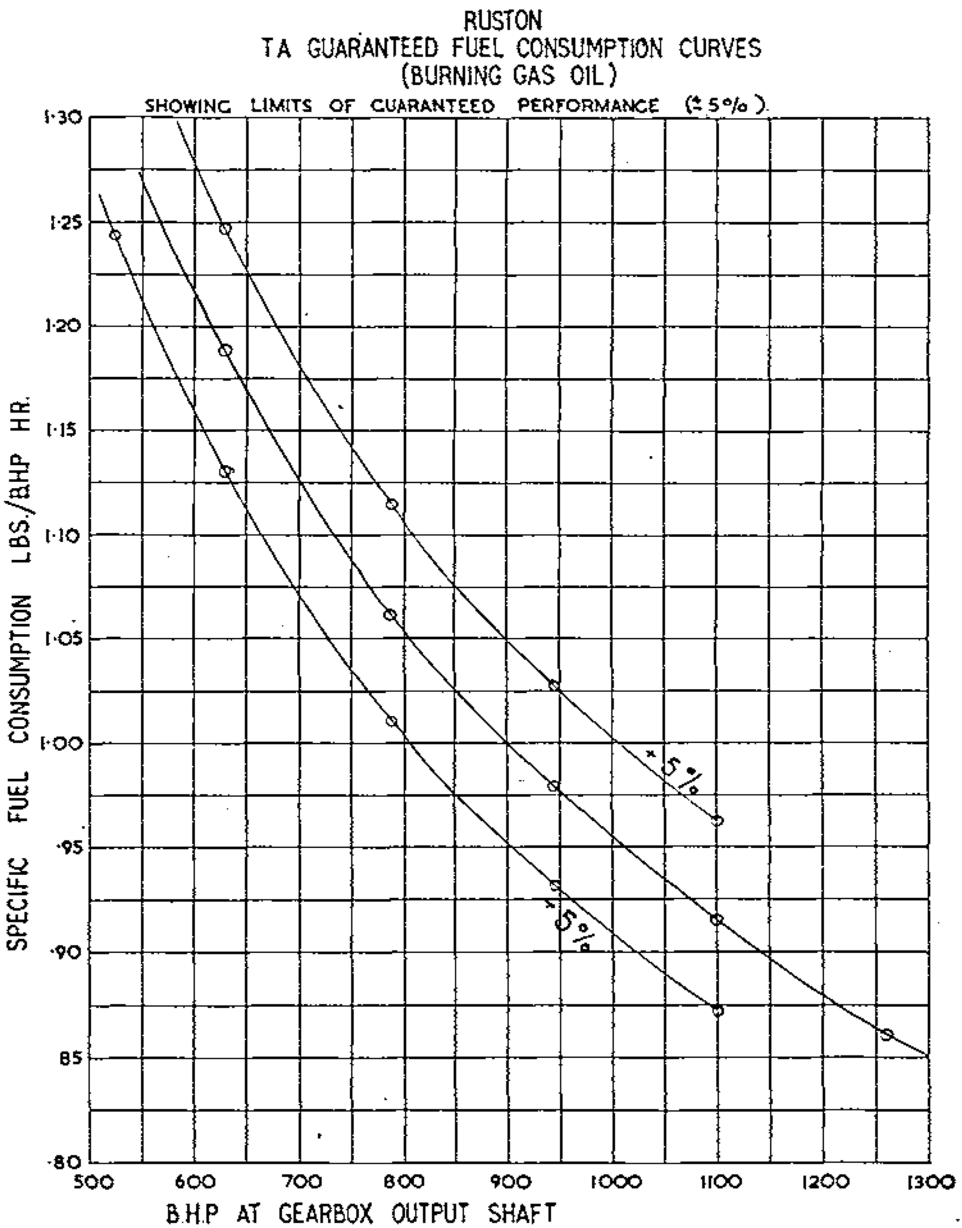
Following upon these two developments, a 180–200 b.h.p. turbine-powered lorry by Laffly was produced in 1951, and in 1952 a 100 b.h.p. C.E.M.A.-Gregoire car. Then came a second Rover car powered by the T8 turbine developing 185–200 b.h.p.

In 1953 came the Turbomeca turbine powered A.F.V. (540 b.h.p. twin engined). In 1954 details of the 370 b.h.p. General Motors Whirlfire G.T. 300 turbine, as fitted to a gas turbine coach, and the Firebird car, were released. This was followed by the Chrysler Corporation's 120 b.h.p. gas turbined Plymouth, the Fiat 200 b.h.p. experimental model and the Austin 125 b.h.p. car.

Almost every Army officer must have seen references in the press in the autumn of 1954 to the experimental 1,000 b.h.p. Parsons gas turbine installed in a tank hull by the Fighting Vehicles Research and Development Establishment. It has been stated that the installation comprises a single-sided centrifugal compressor driven by a single stage axial turbine, two combustion chambers and a two-stage power turbine with built-in gearbox.

Part load inefficiency is at the moment a most important obstacle to automotive turbines, owing to the fact that air mass flow cannot be varied with load and still maintain the high maximum cycle temperature necessary for reasonable efficiency. It is likely that interesting developments in this field will be seen in the near future.

Naturally these gas turbined vehicles have aroused considerable public interest, but it should not be assumed that all successful small turbines are being fitted to vehicles. In 1951, for instance, the Solar aircraft company introduced their 50 b.h.p. "Mars" gas turbine pump which was developed for the U.S. Navy and is now on the civilian market. Much earlier, in 1948, the Centrax Company had produced a simple turbine of 160 b.h.p. and have now in 1954 patented a most interesting and advanced design of small unit with inward flow radial turbines. (It should be noted that this company is now known as "Turbion Ltd".)


RUSTON
TA GUARANTEED FUEL CONSUMPTION CURVES
(BURNING GAS OIL)
SHOWING LIMITS OF GUARANTEED PERFORMANCE (± 5%).
SPECIFIC FUEL CONSUMPTION LBS./BHP HR.
1·30
1·25
1·20
1·15
1·10
1·05
1·00
·95
·90
·85
·80
+5%
-5%
500
600
700
800
900
1000
1100
1200
1300
B.H.P AT GEARBOX OUTPUT SHAFT

The Harwich shipbuilding firm of David Budworth Ltd. released details of their 60 b.h.p. experimental turbine in 1953. This design is notable for its great simplicity. In this year also Sir George Godfrey and Partners announced their 75 b.h.p. turbine.

It has been stated that the Austin Motor Co. are producing a 30 b.h.p. unit for the Ministry of Supply, which was expected to commence its trials in 1954, but the most interesting of all in this field is the 60 b.h.p. Rover 1S/60 designed for small-scale power generation and water pumping.

This was shown at the 1954 B.I.F. It is now in quantity production and may be purchased for £938. The turbine itself weighs only 116 lb. and fitted with a Sigmund pump can deliver 400 g.p.m. at a 231-ft. head. The pump adds 99 lb. to the turbine and the over-all dimensions are then 2 ft. 8½ in. in length, 1 ft. 7½ in. in width and 2 ft. 1 in. in height. The full load specific fuel consumption is 1.46 lb./b.h.p. hour corresponding to a thermal efficiency of 9.5 per cent. The 4½ gallon fuel tank gives twenty-five minutes operation at rated power. Photos Nos. 5 and 6 show the engine-driven pump and a section of the turbine, which also shows the centrifugal compressor and single stage turbine mounted on one shaft. Starting is by the handle shown in the photograph. Electric starting may be incorporated if desired. The engine may be run on a wide range of distillate or gaseous fuels. There is no doubt that this unit is very simple in operation and maintenance and has many attractive possibilities for military use. Rotax-Rover 40 kVA. and B.T.H.-Rover 30 kW. versions for aircraft auxiliary power have already been developed.

Turning now to the upper end of the small turbine category, in 1952 Blackburn and General Aircraft Limited acquired the U.K. manufacturing and selling rights of the French Turbomeca range.

Since then certain alterations and developments have been carried out with a view to nationalizing the designs, and the new Blackburn-Turbomeca 500 and 600 series engines cover a range from 250 to 500 b.h.p. They are intended for all types of application—industrial, transport, marine and aircraft and have a maximum of interchangeable parts, an important military consideration.

The basic engine is the Palas 600, a jet engine based on the French Turbomeca Palas. If the Palas 600 has a power turbine unit attached it becomes a Turmo 600, developing a maximum of 450 b.h.p., and as a free turbine unit this has the requisite torque characteristic for automotive use. An alternative is to have a second stage fitted to the Palas 600 turbine, this second stage being the free turbine unit of the Turmo. A fixed shaft engine is formed thereby, called the Artouste 600 developing a maximum of 475 b.h.p. Another 600 engine is the Marcadau, a turbo-prop version of the Artouste.

There is a reduced mass flow version forming the 500 series. The Palouste, which is an engine providing compressed air by bleeding from the centrifugal compressor, has a mass flow through the turbine less than through the compressor and the Palouste turbine forms the basis of the series, giving a range termed the Turmo 500 (335 b.h.p.), Artouste 500 (345 b.h.p.) and so forth.

The reduced mass flow versions have a better specific fuel consumption owing to reduced combustion losses and leaving loss and a better compressor efficiency. They may be better therefore for normal industrial use, where their lower specific weight is of less importance than in, say, an aircraft. A variety of standard auxiliary equipments may be fitted to these turbines, including hand or electric starting and a reduction gearbox with up to three two-ratio stages, giving output speeds from 1,000 to 3,500 r.p.m.

For maximum continuous conditions the Turmo has a brake specific fuel consumption of 0.92 for the 500 and 1.04 lb./h.p./hour for the 600. Any commonly used distillate fuel may be employed. The Turmo weight is 310 lb. in the British unit, including two-stage gearbox, starter, generator, tachometer generator and engine mountings but excluding instruments. With two-stage gearbox the dimensions of the Turmo 600 are 46.125 in. in length and 21 in. in height, which is extermely compact for an engine of 450 b.h.p. The Turmo is shown in Photo No. 2.

Before leaving small turbines it should not be forgotten that their application to exhaust turbo-supercharging is a most important field which unfortunately cannot be covered in this paper.

Locomotive and Marine Turbines

As with the smaller variety, the great difficulty with locomotive turbines is the high inefficiency at part loads, and although British Railways have been operating two G.T. locos (18100 made by Metrovick and 18000 made by Brown-Boveri) burning oil, the high part load inefficiency combined with low load factor has reduced the over-all thermal efficiency so that it is not much better than steam. Moreover, so far expensive distillate fuel has been used making the whole project most uneconomic. It is understood that operation with heavier oils will shortly commence, however, and the economics should show some improvement.

At present the fuel consumption of the Metrovick loco has been about 2.97 gallons per mile. The Brown-Boveri loco, number 18000, has had a fuel consumption of about three gallons per mile giving an over-all work to fuel ratio of 6.7 per cent, but it must be remembered that this turbine is of a comparatively early design. Brown-Boveri incidentally was the first firm to produce a G.T. locomotive, which was built for the Swiss Federal Railways early in the last war. This particular locomotive has been running on a residual fuel without difficulty and has completed mileage of the order of 250,000.

In the United States the load factor has not been so low as in the U.K. and the operation of gas turbine locos has been more favourable from the economic aspect. There has therefore been more intense activity in this field in the U.S.A. and a sizeable number of plants have been built, installed and operated. One such locomotive is the Westinghouse design, which has been reasonably successful and which includes two 2,000 b.h.p. gas turbo-generators. These have run a considerable mileage on a number of different railroads and most of the initial difficulties appear to have been overcome. Both distillate and residual fuels have been used. Also of importance are the G.E.-Alco 4,800 b.h.p. locomotives. It is believed that over fifty of these are in production, certainly at least twelve have seen service and by mid-1953 600,000 miles had been run on them. They have successfully used heavy residual fuels.

General Electric incidentally were the U.S. fim who carried out the American development of the Whittle type engine and they have, naturally, produced some of the most important American work.

In America, as in Britain, there is much work in progress on coal-burning turbines and there is a 4,500 b.h.p. Allis-Chalmers turbine under development for this purpose although no figures have yet been published comparing its performance with a coal-fired steam loco. A British development is the 1,800 b.h.p. G.T. locomotive by C. A. Parsons and the North British Locomotive Co. Ltd. This differs from most others in that there is mechanical instead of electric drive.

Readers who wish for further information on gas turbine locomotives are referred to an excellent article entitled "World Review of Gas Turbine Locomotives" in *The Oil Engine and Gas Turbine* for May, 1952. Although this article is over two years old it is still the best review of the situation which has been published so far.

As regards marine applications it is first essential to grasp the fundamental difference between naval and mercantile requirements. The naval vessel operates for the greater part of its service at a low load factor, employing its full power only for comparatively brief periods. The mercantile requirement is for long life and reliability at a high load factor. The naval vessel can therefore employ light and compact gas turbines as reserve power which can be brought into use very rapidly when needed, the high fuel consumption for short periods is of less importance than in the case of a merchant ship.

Three heavy gas turbines for commercial use were put in hand in Great Britain after the war and of these the B.T.H. 860 kW. gas turbo-alternator has given the best results, having completed over 10,000 hours running with good reliability and freedom from excessive maintenance. This has led to the development of the B.T.H. 4,000 h.p. gas turbo-alternator, of which two will be used in the Shell 18,000 ton all gas turbine driven tanker, *Hemisnus*. W. A. Allen are also concerned in marine work and are installing a number of 350 kW. turbines in Blue Funnel vessels for auxiliary purposes.

The Royal Navy only became seriously interested in gas turbines after the war, although the U.S. Navy had shown interest much earlier. Nevertheless the first gas turbine propelled vessel to put to sea was the well-known M.G.B. 2009 (since re-numbered 5559) with a 2,500 s.h.p. "Gatric" turbine by Metrovick. This showed the practicability of gas turbines for "sprint" propulsion and the new patrol boats *Bold Pioneer* and *Bold Pathfinder* each include two 4,000 s.h.p. Metrovick G2 turbines for this purpose. Although many difficulties have been encountered with these pioneer vessels tremendous advances have been made.

Attention has also been turned to long-life gas turbines for main propulsion and after initial difficulties and failures the Admiralty have now installed two 6,000 s.h.p. Rolls Royce medium-life gas turbines in H.M.S. *Grey Goose* for main propulsion. In addition to this there has been much interest in gas turbines for auxiliary power and propulsion of small craft and the Admiralty have tested and used engines from a 1,000 kW. Allen auxiliary generating plant down to the Rover T.8 200 b.h.p. turbine fitted in a harbour launch.

It is interesting to note that the U.S. Navy have ordered two of the 4,000 s.h.p. Metrovick and two of the Rolls Royce 6,000 s.h.p. units for installation in patrol boats. Surprisingly, so far, the U.S. Navy have only used a 160 b.h.p. Boeing turbine in a small craft, although a variety of turbines are known to be on order, including a 2,000 s.h.p. turbine by the Allison Division of General Motors and a number of the 400 h.p. Solar Jupiter units.

Free Piston Gas Generators

The free piston compressor is now known to most Sappers, but the variation of the same idea which is incorporated in the free piston gas generator or "gasifier" has not yet been seen to anything like the same extent, particularly, in Great Britain. The subject is worthy of a separate paper but, in general, the free piston principle is used to provide hot gases at an elevated temperature. These gases can then be passed through a turbine to do work as in the conventional gas turbine. The conventional rotary compressor and combustion chamber are therefore replaced by the free piston device. The great advantage claimed for the free piston generator and turbine is the very much higher efficiency and fuel consumption which can be obtained as compared with the normal gas turbine and the results published show a fuel consumption comparable with a diesel engine.

There are a number of different arrangements which can be adopted, these being variations of either "outward" or "inward" compression. Lima Hamilton in association with Westinghouse in the U.S.A., and Sulzer Bros. in Switzerland have been developing outward compression models whereas the Pescara licensees in Europe (Pescara-S.E.M.E. in France and Alan Muntz in England) have been developing inward compression types. The Muntz C.S.75

gasifier, with a suitable turbine gives about 37 per cent thermal efficiency at the turbine shaft and will develop about 350 b.h.p.

In France there has been rather more activity in this field and an 850 ton vessel, *Cantenac*, has been operating with twin gasifiers built by Sigma and turbines by S.G.C.E.M. The G.S. 34 Pescara-S.E.M.A. unit, built by Sigma, which is used in this vessel develops about 800 h.p. and over seventy have been built or ordered for a variety of uses including electricity generation and pumping sets. The French Navy are using a number of them for propulsion of minesweepers. There is also a Renault locomotive with mechanical drive which has been operated for some time on the Paris–Cambrai run. The gasifier turbine in this locomotive develops 1,000 b.h.p. It is interesting to compare this with the Swedish Götaverken Company's diesel-cum-gas-turbine design, also of 1,000 b.h.p.

Bibliography and Acknowledgements

A very great amount of information has been published on gas turbines during the past ten years in the journals of the engineering and scientific societies, in the technical press, by the manufacturers and in many learned books in many languages. Those already concerned with gas turbines will know where to look for the information they require. Those whose interest is more general may care to browse through the following which are available in the Corps Library.

Gas Turbines and their Problems, by Hayne Constant (Todd).

The Gas Turbine Manual, by Welsh and Waller (Temple Press).

Gas Turbines in Retrospect and Prospect, by W. E. P. Johnson, published in the April–June, 1953, *Journal of the Society of Engineers*.

For up-to-date developments the monthly journal *The Oil Engine and Gas Turbine* has the most comprehensive review of gas turbine work, although as readers of *The Engineer* and *Engineering* well know, these journals also contain invaluable accounts of gas turbines and their progress.

I wish to acknowledge the great assistance which I have received, both from the opinions and comments expressed in these three journals over a number of years and from the manufacturers who have supplied data and photographs.

Photo 5.—Sigmund Rover 1S/60 gas turbine driven fire pump.

By courtesy of Rover Gas Turbines Ltd.

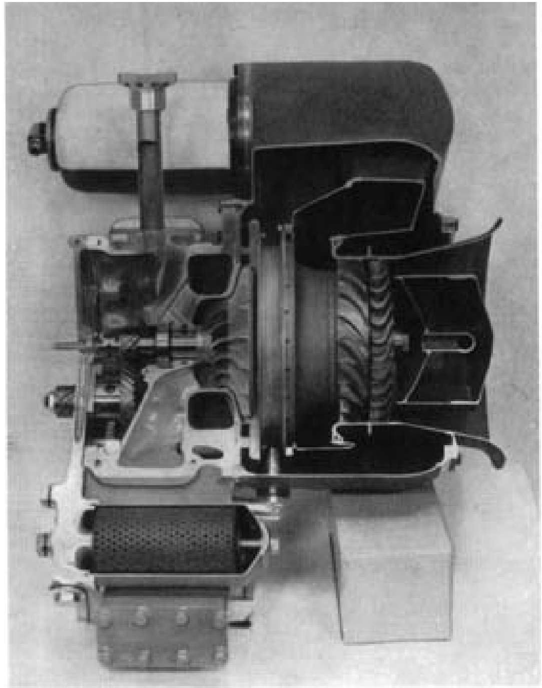


Photo 6.—A sectioned Rover 1S/60 gas turbine, showing the centrifugal compressor and the single stage turbine. The single combustion chamber is at the top.

By courtesy of Rover Gas Turbines Ltd.

Gas Turbines Today 5 , 6

ENGINEERING IN EXTREMIS

By Major J. E. L. Carter, M.B.E., M.C., A.M.I.C.E., R.E.

GENERAL TUCK in his important paper to the Institution of Civil Engineers on "The Engineer Task in Future Wars", reprinted in the *R.E. Journals* for March and June, 1954, referred to the term "broken-backed warfare", coined by Sir Winston Churchill, and dealt briefly with some aspects of it. The June number of the *R.E. Journal* also contained an appeal by Major Crosthwait, in his article "Speed and Surprise in Atomic War" for a new type of mechanized route-opening R.E. unit. The objects of this paper are to carry General Tuck's analysis of broken-backed warfare somewhat farther, to examine the validity of Major Crosthwait's suggestion, and to see whether there are yet other approaches to tackling the extremely difficult engineer problems likely to arise in any future war.

Planning for war nowadays cannot avoid being concerned with three types of war, or, perhaps more accurately, three levels of war; the cold war, the chromium-plated war, and the broken-backed war. There is no need to say more about the cold war, except to point out that economically and militarily it is the foundation from which the other two must develop. Chromium-plated planning, with its insistence on the highest possible quality and quantity in the resources at the disposal of the fighting forces, carried 21 Army Group to victory in 1944–5. Broken-backed warfare, arising from the impact of atomic weapons on the home base and communication zones, may be the crude reality which in fact prevails. A dilemma becomes evident. While fighting a cold war the nation must plan both chromium-plated warfare and for a broken-backed war. It is essential therefore to understand all three levels of warfare and their relationship to each other, so as to ensure that sufficient military effort can be mustered to win final victory whatever form the war may take.

The Equation of Engineer Effort

The main problems of engineering in a broken-backed war can conveniently be isolated and examined by an analysis of the equation of engineer effort for such a war. This equation has only a superficial relationship to the precision of mathematics. It is intended merely as a convenient framework on which ideas and arguments can be hung. None the less in it lie the fundamentals of mathematical truth and the inexorable forces of logistics. These can be neglected by those who plan for war only at the peril of those who have to fight it.

The general equation can be stated as follows:—

$$\begin{array}{c}\text{Available}\\ \text{engineer}\\ \text{effort}\end{array} \times \text{Time} \times \begin{array}{c}\text{Deployment}\\ \text{factor}\end{array} = \begin{array}{c}\text{Possible}\\ \text{task}\end{array} < \begin{array}{c}\text{Minimum}\\ \text{essential}\\ \text{task}\end{array}$$

Photo 1.—Whitlock Dinkum Digger hydraulic excavator mounted on Fordson tractor excavating and loading into tractor drawn trailer

Photo 2.—Autoloader bucket and belt loader on Ferguson tractor base

Engineering In Extremis 1 , 2

Photo 3.—Matbro M 35 Cross Country fork lift truck (humper) on Fordson tractor base at Southern Command Bridging Camp, Wyke Regis

Photo 4.—Matbro Super Loadstar front-wheel drive bulk loader on Fordson tractor base

or, in other words, in a broken-backed war, the available engineer effort applied for a given time, and reduced by all the wastages inherent in applying it over a wide field, falls below the minimum essential task. Engineering *in extremis* indeed becomes the art of the impossible.

The term "available effort" can be expanded as follows:—

$$\text{Available effort} = \text{Planning} \times \text{Organization} \times \text{Morale} \times \begin{pmatrix}\text{Trained} \\ \text{manpower}\end{pmatrix} + \begin{matrix}\text{Applicable} \\ \text{machine power}\end{matrix} + \begin{matrix}\text{Effective} \\ \text{material}\end{matrix}\Big)$$

Planning, organization and morale are fundamental factors in the development of engineer effort. They can, however, do no more than approach ideal levels. Once these levels are reached the scale of effort is controlled decisively by the three resources terms within the brackets. These terms, in total the resources sum, are not independent of each other, nor of the equation as a whole. They involve quality as well as quantity; and planning, organization and morale must be related intimately to them as well as to the tasks to be carried out. In fact Jack must be produced and trained to operate the machines which can be produced to handle the material which can be produced to do the tasks of the broken-backed war. Thus on one side of the equation there is a sum of possible effort, limited primarily by questions of production, manpower and training, though capable of being utterly dissipated by bad organization, planning or morale, and on the other side there are the tasks that have to be tackled.

The Tasks

Clearly all planning must be related first to the probable tasks and working conditions. These have been discussed both by General Tuck and Major Crosthwait, and so consideration of them will be kept as brief as possible. In the terminology of the equation the gross task may be expressed as:—

(Production + Maintenance) × (Communications + Accommodation + Power + Services + Protection + Rescue + Miscellaneous).

In a broken-backed war maintenance of existing utilities and services will be very much greater than in previous wars ; and remembering General Tuck's dictum that it is almost always quicker to rebuild an existing utility than to start afresh, it can be seen that much of the gross task will consist in just keeping things going, or the restoration or reconstruction of utilities by rough and ready methods. In fine, maintenance will be a large factor: production must therefore be kept small; and only a very little new productive work will be possible.

Under the heading "communications", engineer effort will be required on the largest scale for the maintenance of road and rail movement in the home base and throughout the communication zone, and for the movement of shipping in and out of ports. The wide dispersal of airfields and their general independence of built-up areas suggest that they may represent a lesser source of demand on engineer maintenance effort. The destruction of major ports and their associated communication systems will require effort to be concentrated on increasing the capacity of minor ports, and lead possibly to a wide adoption of open roadstead working with lighters, landing craft or amphibians used between ship and shore. The necessity to use minor ports, coupled with the destruction of inland communication centres and the wholesale movement of population and industry, will add immensely to the problems of moving food and raw materials into the base, and war material out of it. Major problems of storage will also arise. At the same time the dislocation of the railway system and the shifting pattern of requirements for the movement of men and materials will lead to increasing demands for the development of road transport capacity. Air transport, dispensing with the bottlenecks of ports, railway junctions and road centres, will naturally play a big part; yet, if there threatens to be a serious over-all deficiency of transport, the theoretical and practical advantages of aeroplanes and helicopters must not be allowed to draw attention too far from the vast existing tonnage carrying capacities of ships, trucks and railway trains.

Accommodation and services will be a major need. The wholesale evacuation or destruction of large towns will impose immense strains on the countryside. The problem will be increased by the requirements for hospitals and evacuated industry. Civilian and troops alike will have to accept living conditions which would have been regarded as intolerable in the past, but even this will not go far towards solving this problem.

There seems considerable scope for thought therefore as to how new combinations of men and machines can be used for supplying large quantities of low standard accommodation during a broken-backed war.

The provision of coal, oil, nuclear power, gas and electricity will make their demands on civil and military engineers. So will the requirements of such protection as is economically possible against the atomic bomb; and so also will the heart-rending processes of rescue. Preliminary demolitions of structures along vital routes in areas threatened by atomic attack may also be needed.

Consideration of these tasks shows that, assessed in terms of brute effort, a very great proportion of the gross task in a broken-backed war will involve the movement and clearance of earth or debris, digging in various forms for protection, rescue and the restoration of services, the production and erection of low standard accommodation, and the repair or renewal of wheel bearing surfaces such as roads, airfields, dock surrounds and other areas required for the handling of stores in transit. Most of this will be extra to the requirements of the last war, and will demand the expenditure of so much effort in the base and communication zones that it is difficult to envisage the possibility of special engineer units, as advocated by Major Crosthwait, waiting with all the resources of modern bridging and route clearing equipment to come forward to help divisional engineer regiments as required. Such units, even if they had been miraculously conjured into existence at the outbreak of war, would inevitably find themselves committed to the ferocious and critical battles of the home base and communication zones. Once so committed there seems little chance that they would ever emerge to play their planned part. In fact, it appears extremely unlikely that in a broken-backed war anything much more than normal divisional and corps engineer regiments would ever be available for use in the forward battle area. If, however, as Major Crosthwait suggests, these would be unable to carry out the normal essential divisional tasks the matter certainly requires very careful examination.

The general problem, however, which must be solved first, is how, in a broken-backed war, to set about bringing the gross available effort into balance with the gross tasks, or at any rate near enough into balance to allow the continued existence of the country and its armed forces, and the continued application of sufficient force to the enemy. To this there are clearly two approaches; to increase the effort and to decrease the task.

Load Shedding

It is not the function of the engineers to say how the so-called essential engineer tasks should be reduced. It is pertinent, however, for engineers to point out that essential is a word of almost infinite elasticity, and that even in the simple process of moving out of a house differences might arise depending on whether or not the house was on fire. If load shedding has to take place, as is axiomatic in a broken-backed war, it is important for engineers to make quite clear, well in advance, how to avoid too much confusion and heartburning in any sudden, and perhaps shocking, change from the planned conditions of the chromium-plated war to the inevitably unpleasant improvisations of broken-backed warfare. It is essential that any suggestions should lead to a real lightening of the load and not, even in subtle disguise, the passing of it on to someone else. In attempting to assess the essentials of broken-backed warfare it must be accepted that as machines and more frightful forms of firepower tend to dominate the field of war so must the soldier increase his personal morale and skill. Only thus will he be able to control his own sources of power and to face those of the enemy. In a broken-backed war the culmination of this process and the confusion and logistic breakdowns on both sides will put a premium on small, lightly equipped, well-trained, mechanized forces which can be readily moved and supported by air. Such forces moving in support of atomic fire power fit into the confused pattern of this type of war.

Heavy tanks, heavy bridging, heavy recovery vehicles, heavy workshops, heavily equipped assault engineers and all the immense logistic tail inexorably linked to the superb fighting vehicles of chromium-plated warfare become absurdly out of place once the logistic backs of the armies on each side are broken, The process, and indeed the very idea, of getting rid of all one's heavy armour, artillery and bridging may be nerve racking and unpleasant, but it is unlikely to be anything like as unpleasant as trying to fight a chromium-plated war on a broken-backed communication system.

In these respects the counterpart in the air of the heavy tank on the ground is the high performance jet fighter. The jet bomber can at least be operated from a reasonable distance behind the fighting area, but the development of the "essential" flying characteristics of the jet fighter at the expense of every logistic consideration of mobile warfare has made it a machine which clashes horribly with the sombre pattern of broken-backed war, or at any rate with such war carried out beyond the reach of fighter airfields previously built in peace-time. Higher performance jet aircraft which are to land and take off vertically are under development, and illustrations of experimental machines have appeared in the press. The advent in quantity of such aircraft would immensely reduce the present utterly back-breaking problem of fighter airfield construction for strategically mobile warfare. Cost, fuel consumption and short flight durations of these planes may, however, make them unsuitable for the general support of land fighting formations. Therefore the engineering and general logistic considerations of broken-backed warfare seem to suggest the need for the development of at least one type of economic and reasonable performance fighter which can be operated off very limited airfields, and thus combine reasonable availability with proper strategic mobility. The new Folland Gnat is a step in the right direction.

No one will feel inclined to throw overboard now much of the finest, most effective, and incidentally most expensive and heaviest equipment of our land and air forces. It is interesting to reflect, however, that in certain quite probable future war conditions the only way in which to continue fighting successfully might be to discard or leave out of battle what we now regard as some of our prime weapons and equipment, and get down to business more in the manner of the later campaigns in Burma and the Far East—fighting with lightly equipped and largely air-supported forces in the atomically-created, logistic jungles of Europe.

Another main approach to lightening the engineer load, inextricably mingled with the whole general question of logistic methods, is covered by the term material handling used in its broadest sense. As the author has discussed this at some length in recent papers in this journal it is not proposed to say much more about it here. Alterations in military material handling methods can profoundly affect requirements for engineer work. Improvements to ships' gear, coupled with the development of mobile quayside mechanical handling equipment, and the introduction of carefully thought out methods of stores loading in parcels, on pallets, or inside special containers can substantially ease the problems of port operation in a broken-backed war. The general introduction throughout communication zone units of mechanical stores handling methods suited to difficult conditions could much reduce the demand for engineer works. The division of responsibility, however, between Engineers, Ordnance, R.A.S.C. and a host of other military and civilian agencies for the provision and movement of military material makes it extremely difficult to take advantage of new machines and methods. Co-ordination through multitudinous committees is a poor substitute for control under a unified command. Supply, storage, movement and maintenance are the four basic activities associated with military material. Can it be said, apart from the recent and remarkable grouping of maintenance under R.E.M.E. that British organization adequately reflects this fundamental fact?

Changes in responsibilities are not easily achieved; but as the development of material handling methods proceeds in this country and in the United States it may well become clear that efforts to rationalize responsibilities in this field may well be amply repaid by the saving of effort in war. A measure of standardization with the Americans on the division of logistic responsibilities might also contribute towards reducing the difficulties of joint material handling development, and many other problems relating to the production and supply of material in the field.

In short the co-ordinated study, development and application of modern material handling methods is essential to the successful prosecution of a broken-backed war.

How to Increase Engineer Potential

Manpower will be limited. It is useless to consider increasing the resources sum by the lavish use of men. Machine power is the obvious alternative, but the machines must be applicable to the tasks of broken-backed warfare, have to be produced in the conditions of such warfare or under the economic restrictions of the cold war, and have to be operated, supplied and maintained. Superficially there appears little difficulty in the idea of replacing men by machines. Becoming machine minded in principle is a matter of delightful ease. The practical application of power to precise military requirements is, however, a very different thing, and once the stage of the academic acceptance of principle is passed, action tends to become enmeshed in a net of practical and psychological difficulties. Unless these can be understood and overcome the conduct of the broken-backed war may perhaps degenerate into the most unco-ordinated process of load shedding.

Task Scales

The development and application of machines is much affected by considerations of scale as well as by the types of task. A very simplified analysis of this follows:—

(*a*) *Large scale.*—In this scale comes major earth-moving and earth-modification tasks such as road building and airfield construction. Such tasks require and justify major items of plant possibly of several hundred brake horsepower each.

(*b*) *Medium scale.*—In this category comes a wide range of widely dispersed tasks involving minor earth-moving, general material handling and general engineering construction. Such tasks individually might each well be completed largely by hand, but taken together may represent a greater total effort than the large-scale tasks. Their complexity makes the employment of machines more difficult; and their wide dispersion and comparatively small scale lead to serious wastages in the employment on them of machines more suited to large-scale tasks. Machines developing 30–40 b.h.p. may be taken as economic in this scale.

(*c*) *Small scale.*—This scale is concerned mostly with the application of power in the form of tools in the hands of individuals. These may range from minor material handling appliances down to fractional horsepower hand tools.

Tasks of all scales may occur together in any project. The application of power in the large and the small tasks is generally well understood; few people doubt the value of major earth-moving plant or of pneumatic tools. It is in the complex middle scale that doubts and difficulties arise; and yet it is in this range that the majority of field engineering tasks lie, and also possibly the greatest total of field engineering effort. The solution of the middle-scale field engineering problem is critical to the solution of the engineering problems of the broken-backed war.

The Middle Scale

In large-scale tasks economy and effect are obtained by the use of robust and expensive plant of considerable power and cost. In the small scale the tools are comparatively cheap and can be economically distributed sufficiently widely to be of adequate value. The middle scale however calls for versatile machines each capable of carrying out a number of tasks, and also capable of being produced cheaply in large quantities. Very large powers are not necessarily an advantage, particularly as these are invariably associated with high cost and weight. To avoid overwhelming the potential operator and fitter manpower the machines must be simple to operate and maintain. In this scale men and machines are frequently required to work together in intimate teams. Machines must therefore be attractive to the men who have to work with them as well as to those who have to operate them. The success of the Bailey bridge lay partly in the appeal it had to the men who had to use it; and indeed appeal to the man is one of the hallmarks of all good military design. Equipment carrying such a hallmark is as great a prop to morale as many of the more publicized means to this end.

Earth-moving equipment came into civil engineering through agriculture. It is significant, however, that although giant machines, largely under the influence of American construction methods, have established themselves in the former field, in the latter the gigantic machines of earlier days have passed away by a process of natural selection. Indeed the failure of gigantism in agriculture, even in America, has been as pronounced as its success in heavy civil engineering.

In well developed countries, agriculture, with its requirements for reasonable quantities of mobile power in a wide range of forms, is now based firmly on the use of the medium, wheeled tractor in the 30–40 b.h.p. range. For specially bad conditions tracked versions of the same machines are available. Such tractors are used either to tow or to operate many types of agricultural tools, or form the bases of a range of machines of agricultural application. Cheapness, durability, simplicity, the general education of farmers in mechanical methods, and the need for mechanization in a man-starved industry have resulted in the mass production of such tractors, and their application to farming in ways which would have seemed unthinkable twenty-five years ago. Indeed writers were stating then the most convincing reasons why tractors would never find an important place in Britain's agricultural economy; yet in 1951, the peak year of tractor production in this country, 133,665 tractors of all makes were produced, and current annual production of Fordson Major tractors alone is about 46,000. In total there are about 360,000 tractors in use in Great Britain. So it can be well appreciated that behind the agricultural tractor is a substantial trained manpower of designers, producers, operators and mechanics.

The agricultural tractor, either in its normal form or as the basis of other machines, has also long had a place in civil engineering, and some place in the Army (mainly for the upkeep of playing fields); but on the whole the country's potential annual output of 4–5 million b.h.p. a year in agricultural tractors is, for military purposes, a largely untapped reserve of mobile mechanical power.

The Agricultural Tractor as a Basic Military Machine

Few will doubt that the tractor has some application to war. The issue here, however, is whether, and to what extent, this type of machine, or machines based on it, can sway the balance of engineer effort in the inevitably desperate conditions of a future war. The basic characteristics of the machine are of outstanding value. The critical question, however, is whether and how the power of the machine can be applied to the tasks which have to be done.

Photo 5.—Weatherill Fordson-based Overloader back-loading over itself into tipper

Photo 6.—Aveling Barford maintenance grader on Fordson tractor base

Engineering In Extremis 5 , 6

Agricultural tractors in Britain are produced on flow production lines designed to turn out a standard article at the lowest possible cost. Apart from certain standard variations which are part of the mass production plan no variations are possible in primary production. It is, however, the practice for a number of smaller firms to take all or part of the primary tractor products, and convert them into a variety of different machines. These may conveniently be described as tractor based machines, and combine the advantages of mass production for the major parts of the machines with the advantages of the special features introduced by the modifications. Tractors can also be used to tow various appliances or to operate a wide range of tools. These appliances and tools are sometimes designed for highly specialized uses, such as weeding between rows of sugar beet. Some may be regarded as mass produced but the majority are produced only in fairly small numbers. Thus it is clear that agricultural tractors can be put to military use in a number of ways:—

(*a*) Standard tractor towing standard appliance.
(*b*) Standard tractor towing special appliance.
(*c*) Standard tractor operating standard tool.
(*d*) Standard tractor operating special tool.
(*e*) Standard tractor modified to a standard civilian type machine.
(*f*) Standard tractor modified to a special military type machine.

Naturally the consideration of military applications of the tractor should be based first on the use of standard appliances, tools and modifications. The towed range includes grass cutters, ploughs, weeders and rotary cultivators; the operated tool range includes saws, pumps, post hole diggers, and hydraulic excavators such as the Dinkum Digger (Photo 1), although this latter appliance, owing to its size, cost and complexity, should really be regarded more as a tractor modification than a tractor tool. The tractor modified range includes machines such as Auto Loader (Photo 2), the Matbro M35 Humper (Photo 3), the Matbro Super Loadstar (Photo 4), the Weatherill Overloader (Photo 5) and the Aveling-Barford Grader (Photo 6).

In very broad figures this type of machine generally costs about £1,500 which is about twice as much as the unmodified tractor without any appliances. The cost of even one appliance such as the Dinkum Digger, or two or three smaller ones added to the basic tractor cost may amount to the same figure. Many of the tractor modified machines can be fitted with alternative hydraulic or otherwise operated appliances.

It is quite clear that certain tractor operated tools such as pumps, post hole diggers and hydraulic excavators are of military value. Such equipments are under trial.

Some of the standard tractor based machines, notably those illustrated in this article, and also the new prototype Matbro hydraulic excavator, are of considerable interest. In the author's opinion, although this is by no means universally held, the disadvantage of modifying the basic tractors so that they cannot be used for operating certain standard tools is outweighed in general by the greater efficiency of tractor based machines in their own fields. Particular attention is drawn to the capabilities of the hydraulic excavators. These machines are small, road mobile at 20 m.p.h., highly mobile across country and capable of digging any standard military weapon pit or shelter in any reasonable ground at a rate equivalent to that of at least twelve tireless men. Owing to their mobility these machines will generally have a higher output than standard tracked or truck mounted excavators when working on a large number of comparatively small and well dispersed excavations.

New standard tools for, and modifications to, standard tractors are continually appearing. It is equally possible for special military tools and tractor based machines to be produced economically, provided that designs are all properly related to the mass produced basic tractors and to the other main standard commercial components and assemblies used in these types of machines.

In short, provision of special equipment of this type for military purposes is perfectly economically possible, provided it is designed within the well established rules of commercial practice.

What special equipment should be produced must be a matter of conjecture, and must await the trials of standard equipment. It is sufficient to say that a number of such equipments are already admirably suited to play a leading part in a war of digging, humping, pumping, dumping, dragging, pushing and debris clearing, and that new types are looming up darkly through the glass which veils the future.

It must be pointed out, however, that the family relationship of machines of the type illustrated in this article is often marred by the fact that the basic tractors are modified by different firms, leading to an unnecessary lack of standardization in secondary hydraulic equipment and other commercial components. It should, however, be possible to remedy this to some extent by official guidance.

The problem of long-distance road movement of tractor based plant can be solved by use of simple tilting trailers of types now becoming available commercially.

Suitable Material

The practical side of field engineering is very much concerned with the movement and handling of large quantities and many types of natural and artificial materials. Up to the last war suitability for manual handling was the prime requirement in the design of military engineering stores. This led in many cases to additional cost, complexity and total weight, but was, of course, perfectly correct in the conditions prevailing at the time. With the extended use of machines these conditions will no longer apply, although the possibility of manual handling must usually still be retained among the requirements of design. All designers of military engineering material should not only exploit the immense advantages which can follow from designing material primarily for use by machines, but also pay due regard to the characteristics of machines as affecting the design of their materials. Many aspects of this problem have been discussed in previous articles, and it is not proposed to repeat them here. It is sufficient to remember the obvious, though often overlooked, principles that machines must inevitably differ from men in their approach to material, that difficulties usually lie in the form of contact between the machine and the material it is to handle, and that inexperience and lack of thought on this aspect of military engineering can go far towards nullifying the value that can be obtained from mechanization. It must be remembered, too, that this applies not only to individual items of stores, but to the same stores in their containers or in parcels or other forms of load intended to facilitate the proper employment of machines.

Trained Manpower

It is essential to the proper development of the resources sum in the equation of engineer effort that manpower must be trained. This means trained to operate or work with the machines required to handle the material or carry out the tasks of the broken-backed war.

Major Crosthwait's reaction to the advent of the machine is a plea for specialization. This in fact means passing the baby from corps and divisional engineer regiments to a new type of trained, mechanical-minded and mechanically equipped unit, on the grounds that there will be neither the machines to equip normal engineer units nor the opportunity to train them.

In fact, as has been shown above, large quantities of simple, effective and economic plant, with a great capacity to supplement heavier and more expensive equipment, can be produced on the basis of the standard medium agricultural tractor. Such plant, in contrast with that produced at high, though often invisible, cost and in prototype quantities as a result of long-term development projects, can be bought economically on a sufficient scale to allow training in mechanized methods from the earliest stages in training regiments, and at the S.M.E., and in regular and reserve engineer regiments of every type. The development of new machines on a prototype basis, without any corresponding development in the real attitude of mind in the Corps towards machines, continued over a sufficient length of time, can lead only to a sense of frustration and a loss of technical morale. Knowledge of machines can come only from experience of machines. There is no other easy road to training.

One thousand tractor-based machines with their ancillary equipment representing less than 1 per cent of one year's tractor production in this country would cost about £1.5 million, but could be used to revolutionize the training of the Corps and its collective attitude of mind. Ten thousand machines at a cost of £15 million would have a profound effect on the whole Army digging problem and the general problem of keeping up the flow of material and men through the communication zone. Machines produced and held on this scale would also allow civil defence authorities to think in terms of military help by columns of perhaps 500 machines or more.

The mention of machines in such numbers will at once raise the old cry against increasing the R.E.M.E. load. It is significant to recall therefore, the number of tractors the farming industry in this country manages to operate, the amount of manpower the machines will release for other essential work, and the contrast between the medical maintenance and other administrative needs in atomic warfare of large labour forces as opposed to the corresponding mechanical needs of the equivalent numbers of simple machines.

The general availability of machines in regular and reserve army engineer units, as part of a really coherent and co-ordinated switch-over from the use of men as a source of power to the use of men as operators of and ancillaries to machines, in conjunction with new equipment emerging from the long-term military development programme, would lead to a great increase in technical enthusiasm in the Corps. Regular and Reserve army recruiting would be favourably affected, and there might well be substantial improvements in the reactions of National Service men.

As part of any such movement for mechanization it would be necessary to insist on officers and men being able to operate a number of machines of different types. Knowledge and ability of this type should become a requirement in officer promotion examinations as well as for the promotion and trade testing in field engineering of other ranks.

It is particularly important that training in these types of machines should not be divorced from general field engineering training by segregating operators in plant schools. The integrated working of mobile machines and men is a fundamental characteristic of modern field engineering in the middle scale of tasks, and it is essential to maintain this conception of team work at all times in the minds of officers and men. From here it might be possible to go on to competitions at regimental sports days and unit "At Homes", and before long such competitions might even feature in the ring of the Royal Tournament at Earls Court.

Planning and Organization

If the engineer resources sum for the broken-backed war is to be dominated by machine power applied on the lines discussed in this paper, engineer planning and organization must fall into line. It is essential that diggers, humpers, humper tools and suitable trailers be continuously available for training at troop level, because it is at this level particularly that the value of machines can easily be nullified by lack of proper methods and of adequate training. At the same time flexibility of organization must be maintained so as to allow the ready concentration of machines for specific tasks. It is also necessary to plan on units being stepped up to three or four times their normal holdings of machines when employed on such tasks as the opening of a route through or around the outskirts of a badly bombed town, or when engaged in a major bridging operation, or in the preparation of a formation defensive position.

It is important to remember in considering the use of these types of machines and machine-operated tools on humping, digging, tree-felling, road-making and even possibly minelaying and wiring, that these tasks are by no means peculiar to engineers. It is quite possible to envisage the reasonable and economic employment of a hundred tractor-based diggers allotted to infantry battalions, artillery regiments and other units, and carrying out all the digging for a divisional defensive position under the conditions of atomic war. The co-ordination of much of this work may well fall on the C.R.E., but there is no reason why a great deal of it should not be carried out by other arms without engineer assistance. Engineer and all arms commanders and staffs will need training and experience in the employment of machines in mass.

The proper employment of machines of this type, coupled with the introduction of new equipments and the general training of officers and men in mechanized methods, should ensure that the Field Engineer Regiment, without any increase in manpower, could give to the Divisional Commander all the support he needs. In fact the capacity of the mechanized elements of the Field Engineer Regiment for continuous back-breaking work might enable divisional engineers in future to carry out much work which in the past would have required help from Corps. This process should allow the centre of gravity of engineer potential to be related more closely to the centre of gravity of the probable engineer tasks, namely in the communication zone.

The emphasis which has been placed in this paper on plant based on the agricultural tractor should not be taken as in any way derogatory to high performance earth-moving equipment. Plant of that type has its own well-known rôle, both in forward units and on major tasks in the rear. It is hoped, however, that the medium-scale equipment, by undertaking many tasks which in the past were allotted uneconomically to major items of plant, will allow a more efficient over-all deployment of the total mechanical effort.

Time

This article is not concerned particularly with the process of slowly building up resources for a major effort at the end of several years of war. Such were the conditions which culminated in the successful operations on the Continent in 1944 and 1945, and such indeed may still be the case in the closing stages of a future war. The effect of atomic attack in a future war, with its potential suddenness and overwhelming impact, will leave little time for the gradual development and deployment of engineer effort. The comparatively low cost of tractor-based machines, and their wide applicability to problems of civil defence and port operation, as well as to the needs of agriculture, light constructional engineering, and the army in the field, appears to justify the creation now of reserves of equipment which can be usefully employed on training in peace-time, and put to immediate use in war. The building up of reserves of this type of plant, so closely fitting into the normal pattern of one of this country's major industries, could be carried out without any undue distortion of the country's cold war economy. Time will not allow adequate action on the outbreak of war, and it will be essential that ample equipment be available from the beginning. Here, perhaps it is convenient to note, that whereas the problem of starting major production of weapons of war, such as jet fighters, is complicated by the fact that such machines may become obsolescent overnight through the development of better machines by a potential enemy, full value will always be available from items of engineer plant of the type discussed in this paper, regardless of whether new and improved types come into service amongst our friends or foes.

Deployment

Engineer plant and other resources are effective only in as much as they are in the right place at the right time. In the conditions of broken-backed war the ability to move resources and concentrate them at points which have been attacked will be of the greatest consequence, and often possibly of considerable difficulty. The lifting of heavy crawler plant by transport is a slow process and involves the use of much expensive equipment merely to move plant from site to site. The over-all output per hour may therefore be surprisingly low. The ability of tractor-based machines to move at speeds of 15–20 m.p.h. along roads under their own power and also readily tackle cross-country diversions at reasonable speeds gives this type of equipment tremendous operational flexibility. A column of 500 machines could, for example, move under its own power from Birmingham to London (108 miles) in about eight hours and set to work immediately on rescue and the restoration of communications. In the same way tractor-based machines could be moved at quite adequate speeds from one defensive position to another during a withdrawal. The lightness of this type of machine would also allow it to be moved readily by air. Tractor diggers, in particular, landed early in an airborne operation might go far towards ensuring early and effective consolidation of the defences around the dropping zone. It is easy to say that fighting troops have always done their own digging and might well continue to do so; but the fact remains that inconspicuous, light and mobile digging machines which can be moved with battalion headquarters and support companies either across country or by air, by helping to dig in mortars, anti-tank guns, regimental aid posts and battalion and company headquarters during the consolidation phase, could contribute largely and rightly to the confidence with which any commander launched an attack; particularly when one appreciates the vulnerability of troops in the open to counter-attack by atomic fire.

Morale

It has already been stated that the maintenance of morale will be all important and at the same time extremely difficult in the conditions of broken-backed warfare. Mechanization can contribute much to the solution of this problem. Machines fortunately have no nerves. One panicky man in a gang of twelve will soon communicate his fears to the others. Fear is contagious. The morale of a crowd will nearly always be lower than that of a select few in the same circumstances. The fact that he is controlling at least a small piece of power, as part of a powerful mechanized unit, will give the individual operator moral stiffening. In the atomic aspect there is one more point: operators working with machines in dangerously radio-active areas can be readily relieved. This would be more difficult with gangs of unskilled labour.

Conclusion

The equation of engineer effort shows something of the play on one another of the various terms and factors which go towards making up the engineer potential for war. There emerges the fact that cheap and effective forms of mobile power must be brought into action if engineer potential is to approach the engineer tasks of broken backed warfare. The agricultural tractor industry is seen to be a ready-made basis for such power, and it can also be seen that the main tractor based machines required already exist. The mechanization of field engineering tasks is proceeding steadily with the development of many special post-war equipments, but the general attitude of mind of the Corps does not appear to be keeping pace with developments either in the military or the civilian fields. Further mechanization on the lines discussed in this paper might appear to add to the problem, but in fact by bringing cheap and simple machines into the hands of junior ranks at every stage of training it can aid the digestion into the Corps of more complex and powerful equipments.

In general, the scale, type and complexity of mechanization suggested in this paper is partly comparable with that of civil engineering and partly with mechanized agriculture, building, and material handling. These last three subjects are just as important as the first for study by the military field engineer. It follows therefore that not only has the military engineer much to learn from his civilian counterpart, but, owing to the probable similarity between many military and civilian engineering problems in a broken-backed war, it is for consideration whether there should not be a steady feeding back into the civil engineering profession of knowledge of modern mechanized field engineering methods. As the development of such methods proceeds it might be of value, therefore, for civil engineers of all grades to attend suitable organized demonstrations of new bridging methods, field soil stabilization technique, military mechanical handling methods and other ways of using machines on tasks which may be of joint civil and military interest in future war.

Finally it is emphasized that nothing in mechanization detracts from the value of the man, and in the broken-backed war his morale and skill will, in the end, be the vital factors in keeping at work the machine in his hands. Engineering *in extremis* may indeed be the art of the impossible, but with suitable combinations of machines and men it may merely be a question of saying that the impossible will now take a little longer than it did in the past.

APPENDIX

List of papers on associated subjects which have appeared in the *R.E. Journal* since 1952:—

Title	*Author*	*Date*
Mechanical Handling of Military Stores	Major J. E. L. Carter	Mar. 1952
Soil Stabilization	Col. E. W. L. Whitehorn	June 1952
The Influence of Mechanical Handling Methods on Engineer Tactics and Technique in the Field	Major J. E. L. Carter	Sept. 1952
The Development of a MEXE Machine	Col. E. W. L. Whitehorn	Dec. 1952
The Construction of Forward Airfields	Capt. T. C. White	June 1953
Produce or Die	Major J. E. L. Carter	Sept. 1953
Some Considerations Affecting the Military Use of the Helicopter	2nd Lieut. M. Smith	Sept. 1953
Palletization of Military Cargoes	Capt. P. K. A. Todd	Dec. 1953
Are you Plant Minded?	"The Duffer"	Dec. 1953
The Engineer Task in Future Wars. Part I	Maj.-Gen. G. N. Tuck	Mar. 1954
Chevalier Island Shipyard	Brig. J. H. D. Bennett	Mar. 1954
The Engineer Task in Future Wars. Part II	Maj.-Gen. G. N. Tuck	June 1954
Speed and Surprise in an Atomic War	Major M. L. Crosthwait	June 1954
The Jerrican Factory, M.E.L.F.	Capt. D. Burton	Sept. 1954
Nuclear Arms and the Service Man	Col. T. I. Lloyd	Dec. 1954

THE PRICE OF LIBERTY IS ETERNAL VIGILANCE

By Lieut.-Colonel P. M. Bennett, R.E.

THIS article was assessed as the runner-up for the Bertrand Stewart Prize essay for 1954. It was written in the spring of 1954 and was based on the following subject matter:—

For many years it has been necessary for a large proportion of the Army to be stationed in the Middle East as a strategic reserve. This has necessitated costly and extensive trooping arrangements for the relief of units and individuals and has meant that regular officers and soldiers are often separated from their families for long periods.

It has been suggested that under modern conditions it would be more economical and better for the morale of the Army if the strategic reserve were stationed in the U.K. with a fleet of transport aircraft permanently available to take it wherever it was required at short notice.

Discuss the advantages and disadvantages of this suggestion and say whether you think it would be practicable.

It is stressed that the views expressed are those of the author alone and are not to be taken in any way as expressing official opinion.

Introduction

One of the greatest difficulties of the military planner at the present time, as indeed of the planner in other walks of modern life, is to determine what are normal modern conditions. Nearly ten years have passed since the end of World War II; some of the conditions, which in 1946 or 1947 were considered abnormal and temporary, must now be considered normal modern conditions likely to persist for a number of years. At the same time scientific development is proceeding at a very fast rate, which will make possible completely new conditions for warfare in the near future.

The dispositions of the British Army throughout the world are dependent on British foreign policy. Any policy for the future of the British Army must be one that will render as effective as possible the influence that the army can exert in support of British foreign policy. It is intended therefore to start this paper with a review of the effect on the army of British foreign policy in the post-war years. It will then be appropriate to consider whether the present army is in fact well constituted either for winning the present cold war or for fighting an atomic hot war.

It will be seen that major changes are considered necessary both in the organization and the equipment of the British Army. It is considered that the army does in fact have a very urgent requirement for a strong strategic reserve based in the United Kingdom, supported by a suitable fleet of transport aircraft. It will be shown that this requirement accords well with the reorganization necessary to prepare for atomic war.

The question of control of transport support aircraft will be considered and the characteristics of transport aircraft required by the army will be discussed.

It is apparent therefore that this paper will range over a wide field, much wider indeed than at first sight might appear justified from the setting of the subject. However, in the opinion of the writer, as the result of scientific development a decisive stage in the history of warfare has been reached. It is impossible to study certain aspects of the future of the British Army without taking into consideration other vital factors.

Great Britain and the United States, together with the other countries of the North Atlantic Treaty Organization, are year by year paying a heavy price, both in manpower and in economic resources, in order to maintain the liberty of Western civilization. If these countries are to be successful in their policies, they must make their armed forces as effective as possible under modern conditions.

Eternal vigilance is required so that the resources available for defence, manpower, science and industry, are used to the very best advantage. Otherwise these resources, which can only with great difficulty be afforded for defence, will be wasted. The price of liberty is eternal vigilance.

The Effect on the British Army of British Foreign Policy in the Post-war Years

Towards the end of World War II, the general public of the Western Democracies had developed a deep admiration for the Russian war effort and were well inclined to friendship with the Russian people. Nevertheless there were warnings from history that the British and American policy of forcing the war to a state of unconditional surrender would lead to a dangerous vacuum of power in post-war Europe and that the policies of the Western Allies and of Russia in filling that vacuum would be likely to conflict. Whether more or less trustful of the intentions of the Soviet Union, planning for post-war conditions in both Great Britain and the United States was, however, based on the assumption that some working agreement between East and West would continue in the years of peace. Public opinion in the Western Democracies dictated that victory should be followed as rapidly as possible by disarmament and demobilization. Both Great Britain and the United States did in fact, in the three years after the end of World War II, demobilize most of their armed forces. By the end of 1948, British troops had been withdrawn from Palestine, India, Burma and all the Far East, except for British garrisons in Malaya and Hong Kong.

By 1948, however, relations between the Western Democracies and Russia had deteriorated to an extent far beyond any that had generally been anticipated at the time of victory in Europe. In 1948 an episode occurred that clarified the relationship between Russia and the West, and established the foreign policy of the Western Democracies. That episode was the blockade by Russia of western land communications with Berlin and the counteraction, by the United States and Great Britain, of the Berlin airlift, that defeated the Russian attempt to force the withdrawal of the Western Powers from Berlin. From the summer of 1948, a state of cold war has been clearly recognized to exist between the Soviet Union and the Western Democracies. It has become the firm policy of Great Britain and the United States to resist Russian attempts at further penetration into the free world.

Meanwhile the balance of power between the Western Democracies and the Communist world was being adversely affected by the revolution that was taking place in China. Generalissimo Chiang Kai Shek, a war-time alley of Great Britain and the United States, was overthrown by a Communist leader, Mao Tse-tung; Communist Chinese armies established a China more unified than had existed for generations. In 1949 the British garrison in Hong Kong had to be strengthened substantially to prevent a possibility of its being overrun by Communist forces concentrated in Southern China.

The policy of the Western Democracies was subjected to a severe test in June, 1950, when the American-protected Republic of South Korea was suddenly invaded by Communist North Korea. President Truman acted promptly and firmly; the challenge thrown down in Korea was accepted by the United States. In the Korean War, that lasted for three years before an uneasy armistice was reached, the United States bore the major share; however a British Commonwealth division, of which two-thirds came from the United Kingdom, established for itself a worthy reputation. It became apparent in the Korean War that the new army of Communist China was very different from the army of Chiang Kai Shek. In old China the profession of arms had long been despised; many of the battles of the Sino-Japanese War were affairs of manœuvre and arrangement between the opposing forces, in which little fighting took place. However the new Chinese Army showed in Korea that it was prepared to fight very hard indeed, accepting heavy casualties in the process. Soviet Russia, already well-off in manpower, had gained an ally with an enormous population, capable of being trained into hard tough troops.

The Communist aggression in Korea made clear to both the Governments and the general public of Great Britain and the United States that their armed forces must be substantially increased. It was obvious that British and American forces in Western Europe must be reinforced and the forces of the Western European nations expanded to a very considerable extent, if the danger of being overrun there was to be avoided. The North Atlantic Treaty Organization was expanded and General Eisenhower returned to Europe as Supreme Commander early in 1951. In Britain a heavy rearmament programme was planned. By an increase of full time national service from eighteen months to two years, the British Army was able in the winter of 1950/51 to form three more divisions, two armoured divisions to strengthen the British Army of the Rhine and one infantry division intended for strategic reserve in the United Kingdom.

For a few years after the end of World War II, the Western Democracies derived a great material and moral advantage from the American monopoly of the atomic bomb. However, Russia succeeded in exploding an atomic bomb in 1949 and a hydrogen bomb in 1953. The development of both atomic and thermonuclear weapons has been energetically continued in the United States; moreover, Great Britain has also successfully exploded her own prototype atomic bombs. Both East and West are therefore physically capable either by design or accident of turning the existing state of cold war into one of atomic hot war. However, the assumption appears justified that the United States is still substantially ahead of Russia in the production and scientific development of atomic and thermonuclear weapons.

There were in 1953 throughout the Western world considerable hopes, derived rather from wishful thinking than from any solid foundation, that Russia, under the new dictator Malenkov, might modify its policy towards the West, which had been, under Stalin, so uncompromisingly hostile. However, the outcome of the Berlin conference early in 1954 made clear that the state of cold war was to be continued as stubbornly as before; the conference indicated indeed that the Russia of Malenkov and Molotov was even more a military dictatorship than the Russia of Stalin, so obstinately did Molotov refuse to compromise on any proposal that might effect the strategic dispositions of the Soviet armed forces in Europe.

In order to summarize the relations between the great powers, it is repeated that a state of cold war exists between the North Atlantic Treaty Nations on the one side and Russia, China and their satellites on the other side. This state of cold war has required the maintenance in Germany of a British army of four divisions; it has also required a British Commonwealth division to fight for three years in Korea and a British garrison much above pre-war strength to be maintained in Hong Kong. This state of cold war might either by accident or design be suddenly changed into a state of atomic hot war. It shows no sign of ending; it must in fact be considered a normal condition in the world today, likely to persist for many years.

The theatres of the cold war are not, however, confined to the countries of North-West Europe or the frontiers of Eastern China, where the interests of East and West openly conflict. For the British Army the conduct of the cold war has been greatly complicated by the forced deployment of troops to other theatres, where local nationalist feelings, encouraged by Communistic propaganda, have resulted in occurrences hostile to British interests. These additional commitments have been the more onerous to the British Army on account of the loss to the British Government of the use of the Indian Army; many times in the course of nearly 200 years resource to Indian troops had avoided the dispatch of reserve forces from the United Kingdom.

The emergency in Malaya has now persisted for six years. The position there has improved greatly during the last two years under the energetic direction of General Templer ; however, it is still serious enough to require the deployment of about two divisions of troops, British, Gurkha and Malay.

This review of post-war British Army commitments has not yet mentioned the Middle East. The question must now be asked, if during the time under review a large proportion of the British Army had indeed been stationed in the Middle East as a strategic reserve, why had reinforcements for the Far East to be dispatched from the United Kingdom and not from the Middle East?

The answer is that there has in fact for many years been no British Army strategic reserve in the Middle East, except indeed for a few months after the defeat of the German and Italian armies in North Africa. There have of course for many years been strong British forces in the Middle East, but they have been committed in that theatre primarily to the security of the Suez Canal and the maintenance there of a British base. Far from a strategic reserve being stationed in the Middle East, emergencies in that theatre have necessitated the dispatch of additional troops from the United Kingdom; for example the rebellions in Palestine, by Arabs in 1936/8 and by Jews in 1946/8.

More recently, in 1951, the Anglo-Iranian oil dispute and the abrogation by Egypt of the Suez Canal treaty required the dispatch from the United Kingdom of two formations, the 16th Parachute Brigade and the 3rd Infantry Division, that constituted the nucleus of a home-based strategic reserve.

For nearly three years a British Army equivalent to three divisions has been committed to the protection of the Suez Canal and the British Base in the Canal Zone; this large force is not, however, a strategic reserve, it is a force committed to that theatre by the deadlock in policy between Great Britain and Egypt. Quite apart from a most serious drainage of regular army manpower that this situation is causing, a vital matter which will be referred to later, this commitment is a heavy burden on the straitened resources of the British Army.

Kenya is another theatre in which the army is deployed to maintain British interests against local nationalist feeling; about a division of British and African troops being committed to suppress the Mau Mau rebellion of the Kikuyu tribe. Whether the present emergency in Kenya will prove of short or long duration, whether or not it should be considered normal under present world conditions, it forms a further example of enforced deployment overseas of forces that should form part of a home-based strategic reserve.

There has in fact been a fresh demand nearly every year since the end of World War II for the dispatch of British forces to some overseas theatre, to sustain British policy either directly in support of the cold war or indirectly where British interests have been locally threatened. Any assumption would appear unduly optimistic that further demands will not arise elsewhere; it would appear more realistic to anticipate that they will indeed arise. It would seem therefore militarily urgent for the conduct of negotiations and of military operations to be pursued vigorously wherever British forces are now committed, so that at the earliest opportunity these forces can be withdrawn home into strategic reserve against further emergencies.

The State of the British Army Today

British foreign policy is to win the cold war in order to prevent the hot war. The cold war must, however, be expected to continue for years; it will be won only if the ability to continue it and the determination to win it are steadfastly maintained. The cold war is maintained at the present time only by great effort on the part of the British people. The cost in money of the British armed forces is a heavy burden on the economy of the country.

It is generally agreed that the cost of defence is as much as the nation can afford; in the opinion of some it is already too much. The cost in manpower is also heavy for a nation short of labour for the manufacturing industries, that have to pay for large imports of food and raw materials.

Even so the British Army is now stretched to the limit of her resources.

In a debate on the defence estimates in the House of Commons on 2nd March 1954, the Prime Minister stated that never before in history had a nation had two years national service and not a brigade of troops to defend herself.

He described it as a situation full of danger but not without honour. It is considered that the present state of dispersion of the British Army overseas is in fact militarily most unsound. The maintenance of a reserve is a basic principle of war. History abundantly proves that success in warfare generally results from conforming to the principles of war, not from ignoring them.

A vital problem in the British Army at the present time is the severe shortage of experienced N.C.Os. which is being rendered more and more acute by the heavy outflow of regular other ranks. For generations the British Army has derived its strength from its regimental officers and regimental N.C.Os.

It is these long-service officers and N.C.Os. who throughout the army form the essential cadres of every unit. Today with national service and short regular engagements, the change over of rank and file and junior officers in a field unit is much more rapid than was formerly the case.

This rapid changeover is unsettling, it detracts from the feeling of stability and contentment, so important to the well-being of any unit. The need today, therefore, is all the greater for a strong cadre of long service regular soldiers to give stability. However, the British Army in the years since World War II has not been able to offer an attractive life to the professional soldier or to his wife and family. For the British professional soldier, much more than for his civilian counterpart, many war-time conditions persist at the present time. Unless he is doing a tour of duty in a training unit, it is probable that he is serving overseas; moreover, service in a training unit is not attractive to many N.C.Os. who prefer to serve in the field army. If a battalion returns home, it is required overseas again almost immediately and has to be reformed with fresh officers, fresh N.C.Os. and fresh men. In 1950, the Northumberland Fusiliers had been less than a year at home when they were sent to Korea; they were hardly a year home from Korea when they were sent to fight Mau Mau in Kenya. Some of the present overseas stations are not family ones; in others there are not enough family quarters. If a man receives a home posting to a home station, he may be unable for some time to get a quarter, because of families, in occupation, of other soldiers serving overseas. The regular soldier, faced with the problem of extending his service, sees the lack of stability of the modern army and the prospect of family separation on the one hand, against the prospect on the other hand of finding a civilian job and establishing a home without difficulty.

Somehow, if the British Army is to retain enough regular soldiers to form the cadres of field units and the staffs of training units, it must be made more attractive. Increases in pay and allowances will not form more than a temporary palliative; they will not constitute the overriding inducement that will stop the present strong outflow of regular soldiers; moreover, the army wants the present tide to be reversed, it would like to see back many who are now leaving. Regular soldiers must again come to feel contented with their service. They will become more contented if there is a better prospect of stability within field units, and of field units completing a tour of home service. Prospects must be improved of family life at home with less frequent separations. These factors that would make the regular soldier contented with his profession, would be greatly assisted by the re-establishment at home of a substantial strategic reserve. The British Army cannot be sustained in being much longer under the present state of all the field army serving overseas; the present state of affairs is losing too many professional soldiers who cannot be replaced.

The disposition of the field army in the many overseas theatres in which it is now located is a matter of politics. It is not the business of the military man to query the decisions of politicians that troops are required to support British policy; on the contrary it is his business to implement such decisions. It is, however, the business of the military man to make sure that the politician does understand the state of efficiency of the military machine. If the duties that the army has to perform are too heavy over too long a period of time, then the efficiency of the army will suffer in the future. As, however, the cold war may last for many years, it is necessary for the army to be maintained for many years at a state of high efficiency. It is not practicable to increase the size of the army; it is already costing, both in money and in manpower, quite as much as the nation can afford. It is necessary then, if the military machine is not to be over-driven, for it to be redesigned and rebuilt, so that for the same cost to the nation it can carry out its duties more efficiently under modern conditions.

The British Government should be demanding urgently from the British Army methods and techniques whereby the army can be altered to be more effective under modern conditions. The present military machine is the same model, with various minor modifications, as the machine that won the last major war. It is a model that would be hopelessly unsuitable for an atomic hot war; it is also a model that is in various respects cumbersome and extravagant for the variety of duties that it has to perform in winning the cold war.

The Army Organization Necessary for Atomic Warfare

The British Army must be designed to be as effective as possible in the event of an atomic war. It was stated openly by the British Government, in their White Paper on Defence dated 18th February, 1954, that it must be anticipated that both sides would employ atomic weapons in the opening phases of a major war. The British Government has announced that British atom bombs are in production for offensive use and that an atomic weapon is being developed for the British Army. In March, 1954, the United States exploded on two occasions, near Bikini in the Pacific, a thermo-nuclear bomb, stated to be several hundred times more powerful than the atom bombs used at Nagasaki and Hiroshima. It is known that Russia exploded an atomic bomb in 1949 and a hydrogen-type bomb in 1953. The possibility of an atomic hot war, in which an enemy atomic offensive would be directed against the main British base, the island of Great Britain, is a truly frightful prospect for the British nation. It is a possibility that is greatly disturbing British public opinion at the present time.

From the military viewpoint, the prospect of a major war being an atomic war is a vital factor that must profoundly influence all planning for the future. It has been suggested that the opening atomic phase of a major war would probably be followed by a period of broken-backed warfare, in which the trunks of both opponents would be paralysed but the hands and feet would be able to twitch feebly. Such a state would in the analogy and in fact for a nation engaged in atomic warfare be an extremely painful state, in which great determination would be necessary to continue the fight. It is essential therefore that the armed forces of Great Britain are as well organized as they possibly can be to fight in an atomic war. Great Britain is most unpleasantly vulnerable to atomic warfare; it is vital, therefore, that her armed forces are prepared for it to the maximum possible extent.

It would be quite impossible in the event of an atomic war to maintain logistically a field army as at present organized and equipped. There would be no prospect, if atom bombs were used by the enemy against the ports and rail centres in the communication zone, of moving forward by sea and land the great tonnages of material required to enable a field army as at present organized to fight. Nor would a vast programme of peace-time dumping do more than delay the time when the field army ran out of commodities, essential to its ability to fight. If a field army is to have any prospect of being maintained in an atomic war, it must be so organized that its total maintenance requirements are about one-tenth of what is now thought necessary.

Reductions in the standard of welfare, such as N.A.A.F.I., E.N.S.A. and mobile bath units, inappropriate as these organizations would become in an atomic war, would not start to deal with the problem. The modern army requires an enormous quantity of material because its organization is based on the tank and on a lavish scale of artillery and of mechanical transport. If an army is to lose 90 per cent of its logistical support it must come down to very light scales of artillery and transport, with practically no armour; it must in fact be equipped on very light scales comparable to the airborne division in the airborne assault. An army equipped with airborne assault scales of artillery and transport would find itself freed from many of the ponderous appendages that encumber the present-day army organized around the tank. The great transport columns required to distribute ammunition and fuel would become unnecessary. The ever-increasing field workshop organization could be completely abolished, enabling skilled technical personnel to be absorbed into fighting units, who could then assume technical responsibility of their small amount of technical equipment, complete assemblies being replaced from the main base. The large engineer effort, now required for the construction of bridges and repair of roads for tanks and other heavy transport, could be greatly reduced. Such savings would make others possible, and the total size of a field division and of the army divisional slice would be reduced very substantially indeed. The logistical requirements of an army in the field could thus indeed be reduced by 90 per cent.

The objection will at once be made that such an army could not effectively oppose an enemy conventionally organized with a full complement of armour and artillery. However, our army at airborne assault scales would be equipped with atomic weapons, and it would be well equipped with effective anti-tank weapons that weigh very little. Moreover our airforce would also be equipped with atoms, and would be conducting a vigorous atomic offensive against the enemy communications, making it impossible for him, dependent on vast quantities of ammunition and petrol, to continue to fight. The fact is that, opposed by an atomic offensive against its rear areas, the conventional army of today with its large quantities of armour, artillery, engineers and transport, would soon become quite immobile; an opposing army lightly equipped and able to fight on a trickle of supplies, would have an enormous advantage. After the enemy offensive had been halted by our atomic counter offensive against his communications, our lightly equipped field army would be well organized to attack, by airborne and air transported operations.

With logistical requirements reduced by 90 per cent, a field army need not be apprehensive of the destruction of its land and sea communications, provided it was supported by a suitable fleet of transport aircraft. This fleet of transport aircraft should be designed and trained to operate from small grass airfields. Such a fleet could in emergency keep fully supplied in battle an army equipped at airborne assault scales. It would be available to transport the field army in airborne and air transported operations as soon as conditions in the land and air battle became favourable. Of course both the conventional army with armour, or the lightly equipped army here advocated, require the support of a tactical air force to create a favourable air situation as soon as possible.

The army required for an atomic war is an army of lightly equipped airborne and airtransportable divisions, armed with effective anti-tank weapons and with some atomic weapons: supported by a transport air fleet to keep it supplied in emergency and to launch it into the offensive when required. Such an army would be able to continue to fight in an atomic war; no conventional army with armoured divisions, numerous supporting artillery and all the additional arms and services would have any prospect of so doing.

It will be argued that the British Army must retain its armour in case a major war should develop in which neither side resorted to atomic weapons. The fact is, however, that Britain cannot afford to retain every weapon in her armoury. The horse had to be discarded in favour of the tank. So armour must be discarded in favour of the atom. Britain cannot afford to be without atomic weapons, she is too vulnerable to them herself. If, however, Britain is to afford atomic weapons and the air power necessary to make them effective, she cannot possibly also afford the tanks and wheeled transport and the other costly furnishings of the field army of today. Britain must have atomic weapons and must make it plain that her whole plan of fighting a major war is based on using atomic weapons to the best advantage. In such a plan lies a real prospect of avoiding a major war.

The Army Organization Required to Win the Cold War

The cold war must be expected to last for years. During that time the British Army has got to remain as ready as possible for an atomic hot war and at the same time produce the troops required in support of British foreign policy in different parts of the world. Further it is essential, if the vital cadre of regular N.C.Os. is to continue to serve, that a substantial reserve should be reconstituted at home. To enable a large reserve to be stationed at home under modern conditions, three requirements are necessary. Firstly the present proportion of the field army committed overseas in support of British policy must be reduced. Secondly units of the reserve must be lightly equipped so that they are strategically mobile. Thirdly an adequate air transport system must be readily available to move them quickly when the political situation so demands.

It has already been stated that divisions equipped at airborne assault scales of artillery and transport, with supporting arms and services very much scaled down, will be essential for an atomic hot war. An army of this type would of course be well suited to take part in most of the cold war operations of the present time, better suited in fact than the present army designed for the mechanized warfare of World War II. With the exception of Korea, lightly equipped troops have been required in every cold war theatre during the last six years. Infantry formations have been required, to man the frontiers in Hong Kong, to fight guerrillas in Palestine, Malaya and Kenya, to guard the Suez Canal Base, to be ready to protect Abadan, to garrison Trieste and to forestall a Communist rebellion in British Guiana. Korea was an exception; it was quite a large war in which armour was used in addition. There may be another cold war theatre such as Korea, in which there is a requirement for armour as a supporting arm. There is also use for light armour, such as armoured cars, for the protection of convoys and patrolling of roads in guerrilla operations. A case can be made, therefore, for the retention for the present in the British Army of a few armoured regiments, one or two equipped with tanks to support the infantry in the larger cold war theatres, such as Korea, and one or two equipped with armoured cars. The elimination of most of the armour from the British Army would enable the number of infantry formations to be increased.

The type of infantry division required for the cold war is, however, a much simpler more lightly equipped organization than either the present-day infantry division or the present-day airborne division, which is as encumbered with transport as its infantry counterpart.

The modern infantry division with its large amount of transport and fire power has tactical mobility, provided it has the necessary logistical backing to be kept supplied with fuel and ammunition. This large amount of transport does, however, greatly hamper its strategic mobility. The problem is enormous of transporting the great quantity of unit transport and fighting equipment from one theatre to another. Nearly all the individual items of transport and equipment in the infantry division will be airportable in the new transport aircraft shortly coming into service with the Royal Air Force, the Blackburn Beverley; many types are indeed already airportable in the existing transport aircraft, the Hastings. Theoretically therefore it could be said that the present infantry division will be airportable when the Beverley comes into service, but the move of an infantry division with its present scale of transport would require a very large air lift. In 1951 both the Parachute Brigade and the 3rd Infantry Division were sent from England to reinforce the Middle East. It was found that the Parachute Brigade could be moved more quickly by sea than by air, if it was to be accompanied by its transport. Troops of the 3rd Division did move by air, but without their transport which followed by sea. If British troops stationed at home are to be strategically mobile for cold war operations, they must be far more lightly equipped, so that a division can really be moved by air to be effective on arrival independent of a sea-tail.

The same type of division is in fact well suited for an atomic hot war, for cold war operations where British policy has to be enforced, and for a mobile strategic reserve. Such a division very lightly equipped with transport and artillery, with other arms and services also much reduced, would be a much smaller formation than the present infantry division. Consequently the total strength of overseas garrisons could be substantially reduced. A larger proportion of the army could be retained at home, organized in similar formations and constituting a strategic reserve that was really mobile.

Airborne Forces

In an army composed of small lightly equipped airtransportable divisions, supported in a major war by atomic weapons, the importance of airborne troops would be much enhanced. If the cold war policy were to retain the maximum number of troops in strategic reserve in the United Kingdom, available for dispatch by air to any part of the world where an emergency arose, provision would have to be made for the establishment of a suitable airhead into which troops could be airtransported. An airborne operation might be necessary to secure an airhead, possibly by seizure of an existing airfield held by unfriendly forces, possibly to enable a forward airstrip to be constructed by airborne engineers. The fact that the British Army was organized and equipped to intervene in an unfriendly situation by establishing its own airhead, in order to move in an airtransported force, would be a factor in support of law and order throughout the world.

In atomic warfare, airborne troops have great potential value as forces suited to follow up an atomic attack. There would appear to be no reason why an airborne assault should not be put in very quickly after an atomic attack, so as to take full advantage of the disorganization and demoralizing effects. It would appear to offer the best prospect of exploiting the use of the atom bomb against certain targets. It is certain that the threat of both atomic and airborne attack would force the enemy to commit large numbers of troops in defence of his rear areas.

At the present time the parachute remains the necessary means of assault of the airborne soldier. The parachute has certain disadvantages and may be superseded in the future by more efficient means of introducing the airborne soldier into battle. This will merely be a change in equipment. The principle of the airborne assault, by one means or another, and hence the requirement for airborne forces will remain.

Transport Aircraft

The case for small lightly equipped divisions both for atomic war and for the protracted cold war is of course dependent on an adequate fleet of transport aircraft. It must be stated emphatically that such a reorganization of the British Army would make it far more dependent on the support of transport aircraft than has up to now been the case. Until now it is only airborne forces that have been vitally dependent on transport aircraft to enable them to function in their normal rôle. Otherwise, with the exception of the XIV Army campaign in Burma in 1944/5, transport aircraft have only been used in support of the Army on comparatively rare occasions; they have been a bonus for special operations. In Burma, however, in 1944/5, the rôle of transport aircraft in support of the XIV Army was much more than a bonus; it was a major factor in the whole plan of campaign. Complete divisions, with their unit transport and fighting equipment, were several times moved from one part of the Burma theatre to another. For months several divisions were simultaneously in action, almost entirely dependent on air transport for all their maintenance. The XIV Army in Burma was vitally dependent on its transport aircraft. At no stage in North-West Europe was 21st Army Group similarly dependent on transport air support; valuable as was the support given by airborne operations, the land campaign would still have been won without them.

If then the British Army were to reorganize on a basis of lightly equipped airborne and airtransportable divisions, it would be necessary for the army's control of transport aircraft to be much stronger. At present transport aircraft are organized in a rather small command of the Royal Air Force. Transport Command has a number of commitments, of which route flying absorbs most of its effort; transport support of the army frequently has low priority. This has been accepted by the army up to now, because the army has not been primarily organized to be dependent on transport aircraft. If the army were reorganized as is now suggested, it would be quite unacceptable; transport aircraft would then become a vital army requirement both for the cold war and for atomic war. It is obvious that the Royal Air Force is comparatively much less keen on transport aircraft.

Transport aircraft would be of very little use, either for the battle of air superiority that would have to be fought at the beginning of a major war, for which fighters and light bombers in large numbers are required, or to constitute the strategic atomic threat against the enemy rear areas and homeland, for which long-range jet bombers are necessary. For the Royal Air Force transport aircraft are not a primary requirement. Moreover, the army has also wanted transport aircraft paid for by the Royal Air Force, consequently at the expense of fighters and bombers. Henceforth the army must find the money necessary both for production of transport aircraft for her existing requirements and for research and development work for more advanced transport aircraft for the future. The money must be found from the existing army budget; it can be found from the vast expenditure on armoured vehicles and heavy mechanical transport of all types. Neither the present system of procurement of transport aircraft from industry nor of control of transport aircraft when in service use is satisfactory for the army. It is not suggested that the Army should itself start to operate transport aircraft; that function should remain with the air force. It is, however, contended that by paying for the development and production of transport aircraft, the army would be in a much stronger position to demand the type and quantity of aircraft that must be procured from the aircraft industry and to demand also a fuller share of transport aircraft in service use.

The types of aircraft in the transport fleet must be well suited to army requirements. If other types are demanded by the Royal Air Force for other functional requirements—route flying or the conveyance of important persons—they must be obtained in addition to the fleet of transport aircraft for supporting the army, over which the army must have the major control. The Blackburn Beverley should prove itself well suited for army transport support; it was in fact specifically designed for this purpose, as the result of experience gained in World War II with bomber or civil transport aircraft adopted for transport support. The Blackburn Universal Freighter, the prototype of the Beverley, has been displayed to the general public for several years at the Farnborough Air Show; much information about its civil and military potentialities has been published in *The Aeroplane* and *Flight*. It is a four-engine freighter, with a lower deck able to carry a double-decked bus or a field gun and tractor, and an upper deck able to carry thirty men. The aircraft is of robust construction, designed to operate from small improvised airfields. Another aircraft specially designed for transport support work, the American Fairchild Packet, has been thoroughly proven in the Korean War to be well suited for airborne and airtransported operations, air supply and casualty evacuation. The Blackburn Beverley should prove itself in service to be still better suited for all these rôles.

It is well to consider what other types of transport aircraft should be developed for army transport support. A jet transport, such as the Comet or a transport version of the new medium bombers, the Valiant, the Victor and the Vulcan, would have a much longer range and be much faster over long distances. No doubt jet transports could be designed to carry some heavy equipment such as jeeps and field guns. A jet transport has, however, the great disadvantage of requiring long runways strongly constructed. The army requirement on the contrary is an aircraft that is largely independent of airfields. Such an aircraft might be any of three types, an assault aircraft, a helicopter or a convertiplane. An American aircraft firm, Chase Brothers, built some years ago a two-engined aircraft of capacity comparable to the Fairchild Packet, which they claimed had landing capabilities as good as an army glider and excellent take-off capabilities as well. There is no comparable British aircraft in production. Possibly the Bristol Wayfarer could be developed as a rear-loading aircraft with a larger payload and improved landing and take-off characteristics; in which case it would prove a useful machine that would increase the flexibility of the transport support fleet. There is certainly a sound argument for a robust two-engined aircraft of about 15,000 pound payload, complementary to the Beverley; it would be considerably cheaper and for certain tasks more suitable. The army should encourage vigorously research and development of techniques for improving the landing and take-off capabilities of transport aircraft; the more improvement that can be made, the more reliable and flexible will become the air transport support of the army in the field.

Further, in the future, transport aircraft are required that can operate quite independently of airfields. Helicopters are still in their early stages of development, probably about the stage of fixed-winged aircraft of 1916. However, technical knowledge in the aircraft industry has greatly advanced in the last forty years. Great progress has been made in the applied sciences of aerodynamics, metallurgy and heat engines. Given adequate support, the progress in development of rotary-winged aircraft should proceed rapidly. Rotary-winged aircraft of ten years time may bear little resemblance to the helicopter of today. On both sides of the Atlantic some study is being made of a convertiplane, an aircraft with the vertical landing and take-off capabilities of the helicopter and the range, speed and payload capabilities of the conventional fixed-winged aircraft. Such an aircraft would be of enormous value for transport support. To summarize the case for helicopters, it is considered that they have now some uses but are still in the early stages of development. Potentially they have very great possibilities for army transport support; they will be of far greater importance for the army than for the air force. It is therefore the army that should encourage helicopter research and development and expansion of the helicopter industry. It is not reasonable to expect the Royal Air Force to devote much effort or money to helicopter development; money must be found from the army budget.

Conclusion

A state of cold war clearly exists between Great Britain, the United States and other Western Democracies on the one side and Soviet Russia, China and their satellite countries on the other. It must be assumed that this state of cold war will exist for many years. The policy of the Western Democracies is to win the cold war in order to prevent the hot war. In the event, however, of the outbreak of a major war, it must be expected that both sides will use atomic weapons. The best prospect indeed that international relations will not cause another major war lies in the effectiveness of the international law of common funk. The main British base, the United Kingdom, with its dense population, is unpleasantly vulnerable to atomic attack. It is essential therefore that the British nation is itself well equipped with atomic projectiles and the means of delivering them. It must be firm British policy to use atomic weapons if forced into another major war.

The British Army today is an armoured and highly mechanized army. It is an army dependent on the assistance of large supporting arms and administrative services. The logistical difficulties of maintenance of such an army in the field are very great. An atomic offensive against the communication zone of such an army would make maintenance impossible. An army of armoured and highly mechanized divisions is in fact now obsolete, as obsolete as an army of horsed cavalry. It would only be required in a major war, but in a major war it would be impossible to maintain. The British Army required for an atomic war is an army of small very lightly equipped divisions, able to fight with one-tenth of the supplies necessary to the field army of today. It must be equipped with an atomic weapon and, as long as the potential enemy has much armour, with effective anti-tank weapons.

It should be assumed that whilst the cold war continues, fresh demands will continue to be made for the deployment overseas of the British Army. An important aspect of British policy should be therefore to reduce the commitments of the army overseas, so that as much as possible can be withdrawn into a home-based strategic reserve, available for fresh demands. The forces required for cold war operations are mainly lightly equipped troops. The requirement is light infantry divisions, trained to move and fight really lightly equipped, as were airborne troops in their early days and as was XIV Army in Burma. The supporting arms and services within such divisions and the extra-divisional support required by them would be very much reduced. The employment of such small lightly equipped divisions in the theatres of the cold war would make possible a substantial reduction in the total number of troops committed. Consequently more troops would become available to reconstitute a home-based strategic reserve.

The type of division required by the British Army is the same, for the overseas theatres of the cold war, for the cold war strategic reserve, and for an atomic hot war. The requirement is a light infantry division, with greatly reduced scales of supporting arms and services, trained to move and fight with very little transport. It is a division that really is airtransportable. A proportion of these light divisions should be airborne, that is to say trained in the airborne assault, by parachute or by other means.

The maintenance of a reserve is a fundamental principle of war. The history of warfare is full of warnings that principles of war cannot be broken without serious consequences. It is therefore an obvious military requirement, in the existing state of cold war, that an adequate strategic reserve should be reformed as soon as possible. The British Army is still vitally dependent for the maintenance of its traditions, morale and efficiency on a cadre of contented long-service regimental officers and N.C.Os. At the present time conditions of service in the British Army is not attractive to this cadre, which is becoming seriously depleted. The establishment of a substantial home-based strategic reserve would provide a prospect of home service for units of the field army. This would be a powerful factor in making continued service in the British Army more attractive to the regular soldier.

The land battle will continue to be profoundly influenced by air power. Whether the field army is the ponderous mechanized army of today or the lightly equipped army advocated in this paper, it requires a favourable air situation to be established as soon as possible in the theatre of operations. The Royal Air Force requirement for combat aircraft, fighters and bombers, for the air battle, is in concord with the army requirement for offensive air support in the land battle. The vulnerability of the land and sea communications of the field army to atomic attack will, however, enhance the requirement for transport air support. Further an army of light divisions with little mechanical transport would have limited tactical mobility without a good system of air supply.

The influence of airborne troops in the land battle will be increased. The army in fact will become vitally dependent on transport air support.

The more the army becomes operationally dependent on transport air support, the more the army must increase its influence on the development, procurement and operational control of transport aircraft. There are in existence suitable types of transport aircraft that meet the army requirements for the cold war and for an atomic war. For the future it must be the policy to develop transport aircraft that are operationally independent of airfields; energetic research and development is required with this aim in view. If, however, the army is to obtain procurement of the quantity of transport aircraft required, adequate control of these aircraft in service use, and sustained research and development effort for transport aircraft of great potential value, then the army must be prepared to finance the large expenditure required from the army budget by rigid economies in other army equipment.

The development of atomic and thermo-nuclear weapons has effected a revolution in warfare. The present organization of the British Army is not suited to atomic warfare or to the existing state of cold war. If the liberty of our country is to be retained, eternal vigilance will be necessary that the British Army, with the Royal Navy and the Royal Air Force, are maintained in as effective a state as possible under whatever conditions prevail in the modern world. The price of liberty is eternal vigilance.

THE MYITNGE PROJECT, 1946

In this article, which was published in the September, 1954, *Journal*, the author described the use of a modified gas mask for diving purposes. He stated that the diver plugged his ears with cotton wool and grease.

It has since been pointed out that the practice of plugging the ears when diving is, according to some authorities, very dangerous as it prevents the equalization of pressure on both sides of the ear drum.

In the article, however, the author clearly states that the divers who did not use ear plugs suffered from ear trouble, whereas with the plugs the diver had no trouble. He explains, however, that it was necessary to halt every 10 ft. on the way down to allow the pressure to equalize.

It is obvious therefore, that great care must be taken with the ears if any form of improvised diving apparatus is used.

AN OBJECTIVE FOR HOME DEFENCE

By "BENBOW"

Forget six counties overhung with smoke
Forget the snorting steam and piston stroke
Forget the spreading of the hideous town
Think rather of the pack-horse on the down
And dream of London, small and white and clean
The clear Thames bordered by its gardens green.

WILLIAM MORRIS,
The Earthly Paradise.

THE Committee on Home Defence had again been discussing their vexatious subject. They had done some useful work on emergency measures for the immediate future, and now they had passed on to consider longer-term requirements, but on this they had been able to make singularly little progress. The reports of high-powered sub-committees on target areas, dispersion, emergency communications and the like had been mulled over and over, but all the measures proposed seemed either ineffective or else quite beyond the economic capacity of the country. It was with a feeling of exasperation that, after a desultory argument of an hour or so, the members of the Committee turned to the chairman, who, unusually for him, had been taking no part in the discussion, but had been sitting with a rather detached and smug look on his face.

"I had a dream last night."

Ten pairs of eyebrows raised in mild, tired surprise.

"I have been grappling with this intractable problem for some time now, and I am persuaded that it is not one to which any short-term solution can be found. Palliatives are all we can hope for in the near future—that and excluding as far as we can the possibility of war. *But,* however long we may succeed in staving off total war, we must recognize that this island, with the ever-increasing power of weapons of mass-destruction, is becoming far more vulnerable than any other major power, and that sooner rather than later, if we let things drift, we shall find ourselves open to blackmail by the mere threat of attack by any power capable of delivering it. We therefore need a long-term plan—a very long-term one—designed to reduce this vulnerability to less tempting proportions. If we do not, in our generation, do something toward getting such a plan under way, we shall rightly be execrated by posterity, if indeed any posterity will have survived to execrate. I have always admired the outlook of the forester. He plants slow-growing trees, such as oaks, which will certainly never benefit him, but for which his great-grandchildren will bless him. That is the spirit in which we ought to approach this grave affair. The issue is the survival of our race with all its accumulated and hard-won wisdom.

"Now I find that the most baffling thing is to visualize what the eventual pattern for this country ought to be. There are so many unknown factors even in the not-too-distant future—the size of the population, the sources of power, changes in the economic pattern, and many others. Well, last night I was thinking round in circles on these lines, until I could think no longer, and presently I fell asleep. It was then that I had my dream."

He glanced quizzically round his now attentive audience.

"Now this dream was so vivid and made such an impression on me, that when I woke up, I sent for my secretary and at once dictated all I could remember of it. This is the result, which you may care to read at your leisure. We will talk about it to-morrow."

He handed round a paper, which the members took away with them, and this is what they read.

* * * * *

I found myself in St. James's Park, on the bridge. It was a fine spring morning, and at first it all looked very familiar, with people feeding the ducks. But I soon noticed that everyone looked very clean and well groomed, and their clothes were strange. Colourful and much looser and more comfortable-looking than ours, and of a pleasing cut. I could see Buckingham Palace with the Royal Standard flying, but Wellington Barracks looked different—they had evidently rebuilt it, so it must have been a *very* long time ahead! Turning round, I was surprised to see no sign of that rather oriental view of the buildings of Whitehall, nor of any other buildings either along Birdcage Walk or beyond the Mall, with the exception of St. James's Palace. Over the trees, I could see Big Ben and the Houses of Parliament, glowing golden in the sunlight. It seemed quite natural, in the odd way of dreams, that I had a companion who seemed to know all about me. His accent was peculiar, a kind of blend of cockney and American, as he suggested taking a look at the city from the top of Big Ben, to which I readily agreed. As we walked across to Birdcage Walk, he told me he was a Cambridge professor of history, and specialized in twentieth century customs, manners and language. I expect that accounted for his rather precise, though idiomatic enough, way of talking.

"If I spoke in our present-day idiom" he said "you would scarcely be able to understand me."

We got into his car, which had a transparent roof and ran very quietly. As we passed Great George Street, I asked where the Cabinet Offices were. "Where they have always been" said he "but some 500 feet lower down. If you look carefully, you can see the hot air coming out of those ventilators hidden in the shrubbery." I could indeed see a shimmer rising in the cold spring air over quite a wide expanse of garden. "And the key parts of the various departments are also near by. You must have some concentration at the seat of government, and as London is no longer a target, they decided it might as well be here as anywhere else. Besides, there are sentimental reasons. There are, of course, several alternatives. By the way 10 Downing Street is still on the surface, as a gesture to tradition. There it is, through the trees."

We soon got to Big Ben, went up in a lift and stepped out on to a platform commanding a familiar, but unfamiliar, view. My first impression reminded me of those new, artificial, administrative capitals, such as Washington, New Delhi, Canberra, which are not based on an ancient commercial city. There were the great green spaces and vistas, with handsome buildings lying infrequently among the trees. Yet there was a difference. One could not detect any general pattern, like the radiating avenues of Washington or Delhi, nor were the buildings new and of a period. Yet there were vistas, such as the Mall, and evidence of pleasing but irregular design. The buildings were for the most part old and well known. St. Paul's rose out of the trees to the north-east, in splendid isolation. Nowhere, as far as the eye could see in any direction, did any mass of buildings appear. There was no sign of the docks. The river wound between green lawns and wooded banks. The open spaces all round seemed to be filled with pleasure gardens, parks and playing fields. Above all, there was no smoke. None whatever.

In the direction of Hyde Park, I could see silver shapes apparently popping out of the ground at regular intervals and vanishing in contrails into the upper air. As regularly, others arrived and disappeared gently into the ground. "London Airport" said my guide, "They take off underground from the bottom of vertical funnels and land the same way. This avoids the disturbing effects of surface winds and also reduces noise."

"But where is London?" I asked "Underground too?"

"Oh dear me no!" said he, "That would be a fantastic and dismal project and quite beyond practical politics. Only certain offices which would be vital in war are underground. The fact is, London as such no longer exists. I shall have to explain on a map of Great Britain. Shall we go down?"

He took me down into a room in the Houses of Parliament, on the wall of which was a large map of the British Isles. This was designed to illuminate certain features on pressing corresponding switches in a long row beneath.

"The Committees find this most useful" he said. "I expect you would like to see the built-up areas first? There you are."

He pressed a switch. There appeared, picked out in red light, a network, looking like a road map, but with a curious feature. At all the main nodal points, which I recognised as the present big towns and cities, there was a large blank space.

"You've pressed the wrong switch" I said "those are the roads, surely."

"Oh no!" he said "*these* are the roads!"

He pressed a second switch, and another, much finer network, in blue light, appeared. A thin blue line ran along the centre of each red line, and a fine venation of minor routes appeared between them. Also, the main blue lines continued through the blank spaces where there were many intersections. Outside the blank spaces, there were a varying number of more or less concentric blue rings. I was still puzzling over this when he said "I had better explain about the towns. There aren't any, as you know them. The pattern you see was based upon two principles, first conceived way back in 1955. They might be described as, firstly, 'The Green Bull's-eye' and secondly, 'Compulsory Ribbon Development'."

I must have shown a look of pained surprise, for he repeated, "Yes, Compulsory Ribbon Development—but not quite as you knew it. Your old towns and cities grew up around centres of communication, and were danger-spots for two reasons; because of the concentration of population and industries around them, and because they *were* centres of communication. Now, if you remove the surrounding population and industries, those centres of communication are not nearly so vulnerable as such; for it is the debris of fallen buildings that is the main cause of interruption. If there are no buildings, only ground-burst weapons can seriously interfere, and to circumvent those, you must have plenty of by-pass routes at a considerable radius from the centres. Remember that the crater of a ground-burst weapon is far smaller than the circle of severe structural damage caused by a similar air-burst one. So what we have done, in general terms, is to remove all living and working accommodation from the centres of communication, and to replace it with recreational and agricultural areas. These areas contain, at a low density, non-vital buildings such as ancient monuments, sports stadia, theatres, restaurants and so forth. You can see the roads on the map —now let's look at the railways."

He pressed a third switch and a green network appeared. It struck me that this was less dense than our present railway system, and I saw that all the nodal points were by-passed and encircled. My friend went on "We only use the railways for very fast, long-distance traffic—200 m.p.h. stuff. And it's all monorail. Your duorail went out long ago. Monorail is faster, and easier to maintain and repair. Many of the old railway formations have been converted into high-speed multi-lane roads.

"Now consider the Green Bull's-eyes again. The majority of major internal roads of the old cities are preserved among the parks and gardens, giving a maze of alternative routes, which it would be almost impossible to interrupt completely. This does not apply to the monorails, which are taken outside.

"You realize" he said "that even if the rings are broken, there will still be ways round for the railway— it is impossible to destroy the mesh completely. And anyway, monorails are quickly relaid, on a new alignment if need be, being far more tolerant of geography than the old railway.

"But you are wondering about housing and industry, and this has a direct bearing on the actual size of the green centres. It is all based on the undoubted fact that no one has yet invented a bomb that will explode in a straight line—and probably never will. Thus a bomb which would have a devastating effect on a built-up *area* (an ideal target), would be largely wasted against thin *ribbons* of population, provided those ribbons had adequate separation."

"But why not go in for area dispersion, to a similar low density, instead of ribbons?"

"Because that would require thousands of miles of uneconomical roads and service mains and would waste good farming land. It is a matter of amazement to us how you squandered your heritage of productive soil in your sprawling housing estates and enormous air-fields. A staggering waste of money and effort, all of which we have had to undo and replace."

"But" I still objected "you would need hundreds of miles of ribbon to accommodate one fair-sized town!"

"That is just what defeats the bomb-aimer. Now the planners, when all this started, decided on a minimum separation of 5 miles between population ribbons, and this was the ruling factor in the whole layout. The reasons were highly technical, and also involved some crystal-gazing, but, briefly, it was thought that, with this separation, no single *fissile* weapon would ever be capable of destroying more than about five miles length of ribbon. As for thermo-nuclear weapons, their possible size is unlimited, but the larger they are, the more of their energy, and therefore of their production effort, is wasted. All we can do is to present an untempting and unrewarding density. If you assume a hydrogen bomb capable of destroying utterly the whole of your Greater London (say an area 25 miles in diameter, with a population of some 8 million and a large chunk of the national industry), the same bomb ideally placed in *our* population and industrial mesh could only hope to destroy, *at the most*, about ninety miles of ribbon, with a population of half a million and perhaps a hundredth part of the national industry. It makes a difference, you will agree. And considering the immense effort required to produce and deliver even one such bomb, and the retaliation invited, would anyone but a maniac seriously consider it for such indecisive results?

"Now you can see how the 'Green Bull's-eyes' are sized. Diagrammatically, it's like this (Fig. 1). There must be five miles separation between adjacent ribbons each side of the 'bull', so that it must have a minimum radius of about 3½ miles. Other ribbons start at greater distances as the increasing separation of the innermost ones allow. Of course, in practice geography and existing routes play a part, but the principle is followed. Here is an example of the area round Norwich before and after treatment. (Figs. 2 and 3.)

"You will notice that big cities like London and Birmingham have much bigger bulls. That is because there is no one centre of communications, but a large complex of centres and the bull must embrace most of this complex. In the case of London, most of the old Metropolitan Area is included. But at smaller nodal points, the 3½-mile radius rule applies, and even where ribbons cross, the minor one ceases 5 miles each side of the major.

"You are wondering no doubt how we get enough length of ribbon. Well, the ribbons are based for the most part on the old first-class roads, the 'A' routes. In your day there were about 30,000 miles of these in the United Kingdom. Assuming only a quarter of this mileage available at 5-mile separation, that gave 7,500 miles available for building. Our population is now only 20 million owing to the gradual redistribution of population and industry in the Commonwealth. Old urban areas and airfields have been put under cultivation again and you would be surprised how much good land has been rewon. Of course you would hardly recognise the old 'A' routes now—they are all at least four-lane—and there are a number of 'S' routes for very fast long-distance traffic. However, an available length of 7,500 miles gives a population density of 2,800 per linear mile, which is about the same as that of your ghastly old-fashioned ribbon-developed roads.

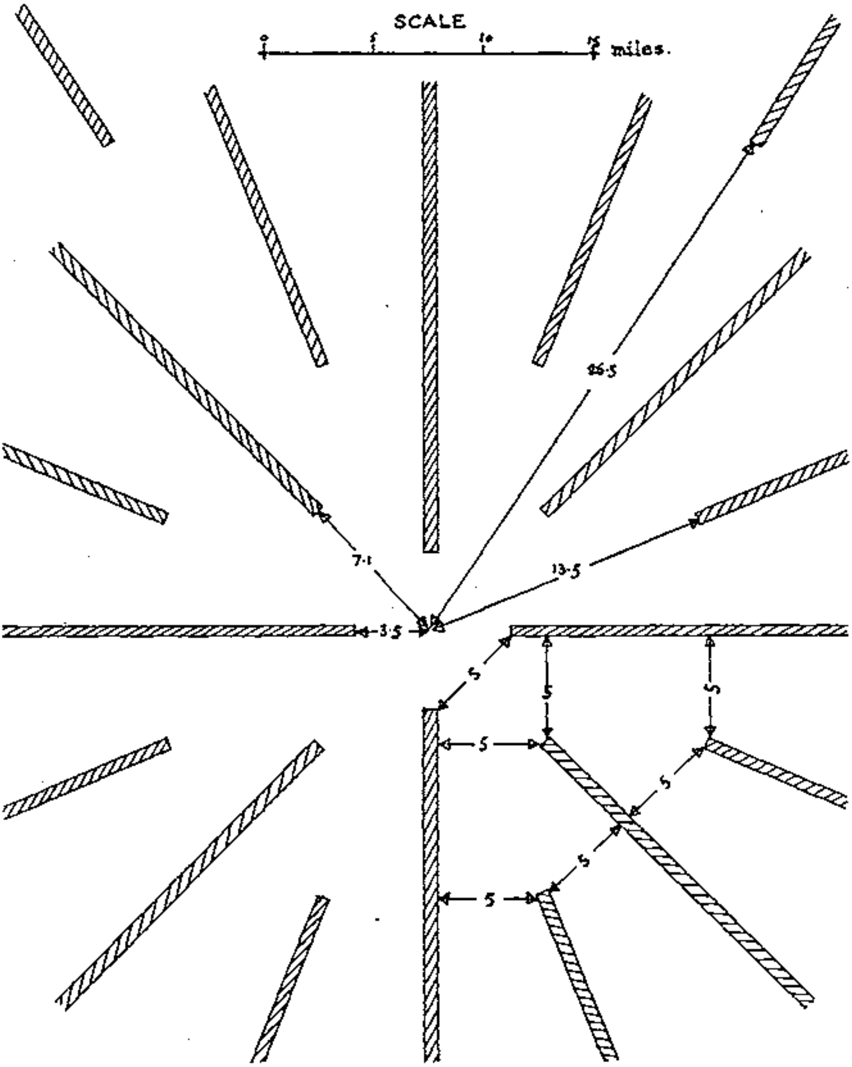
"But there is a great difference. We long ago accepted the fact that, space being short, we *must* make more use of the third dimension and finally abandon, rather regretfully, the idea of giving every man his own back garden. Our housing strips consist of large multi-storey apartment buildings, each housing perhaps 500 people. The blocks are at least 200 yards apart and 200 back from the road, with a further space behind, so that there is plenty of space around them for light, fresh air and amenities. And there is no chance of the roads themselves being blocked by debris. Here is a diagram (Fig. 4) of a typical ribbon-avenue. You will see that its total breadth is around 1,000 yards. The buildings vary greatly in size and character, and you will find no lack of scope for architectural ingenuity. The density is about 6,000 per linear mile. So we have plenty of spare room—in fact we could house 45 million easily without going in for skyscrapers."

I did not like the idea of rows of blocks of flats spreading all over the countryside, and did not think many people would take kindly to flat life, instead of having a little house and garden, and I said so.

"At the 5-mile spacing," he answered "you can seldom see more than one row of buildings at any time, and they are not unlovely. The avenues are really very fine. The roads are lined with trees and

figure 1.

DIAGRAMMATIC DISTRIBUTION OF POPULATION STRIPS ROUND A CENTRE



ALL DISTANCES ARE IN MILES

DIAMETER OF CIRCLE	5 MILES	25 MILES	50 MILES
LENGTH OF RIBBON ENCLOSED	0 →	60 →	250 →
POPULATION AT 6000 PER LINEAR MILE	· 0	360,000	1½ MILLION

AVERAGE POPULATION DENSITY IN 50 MILE DIAMETER CIRCLE = 750 PER SQ. MILE.

figure 2.

NORWICH *BEFORE TREATMENT*

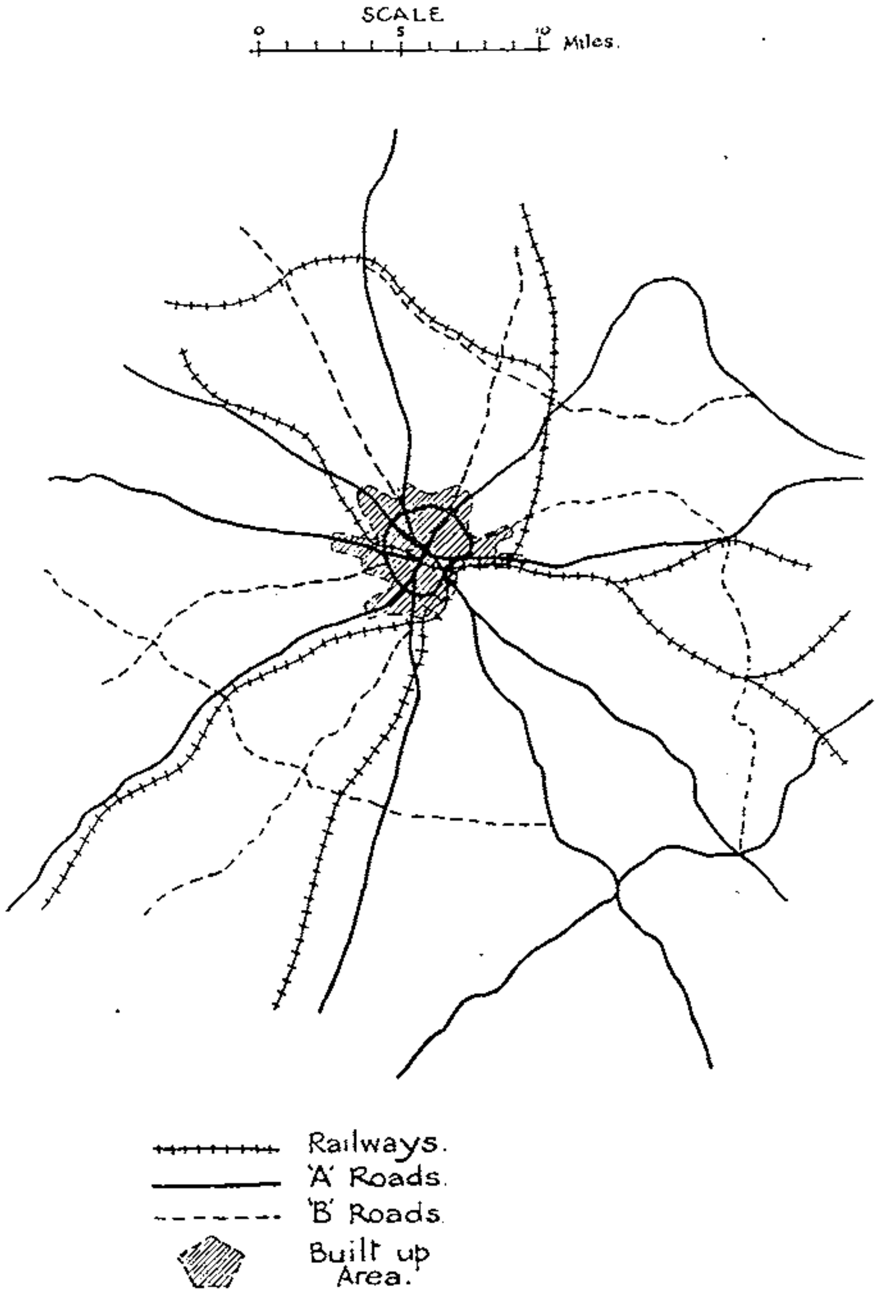


figure 3.

NORWICH *AFTER TREATMENT*

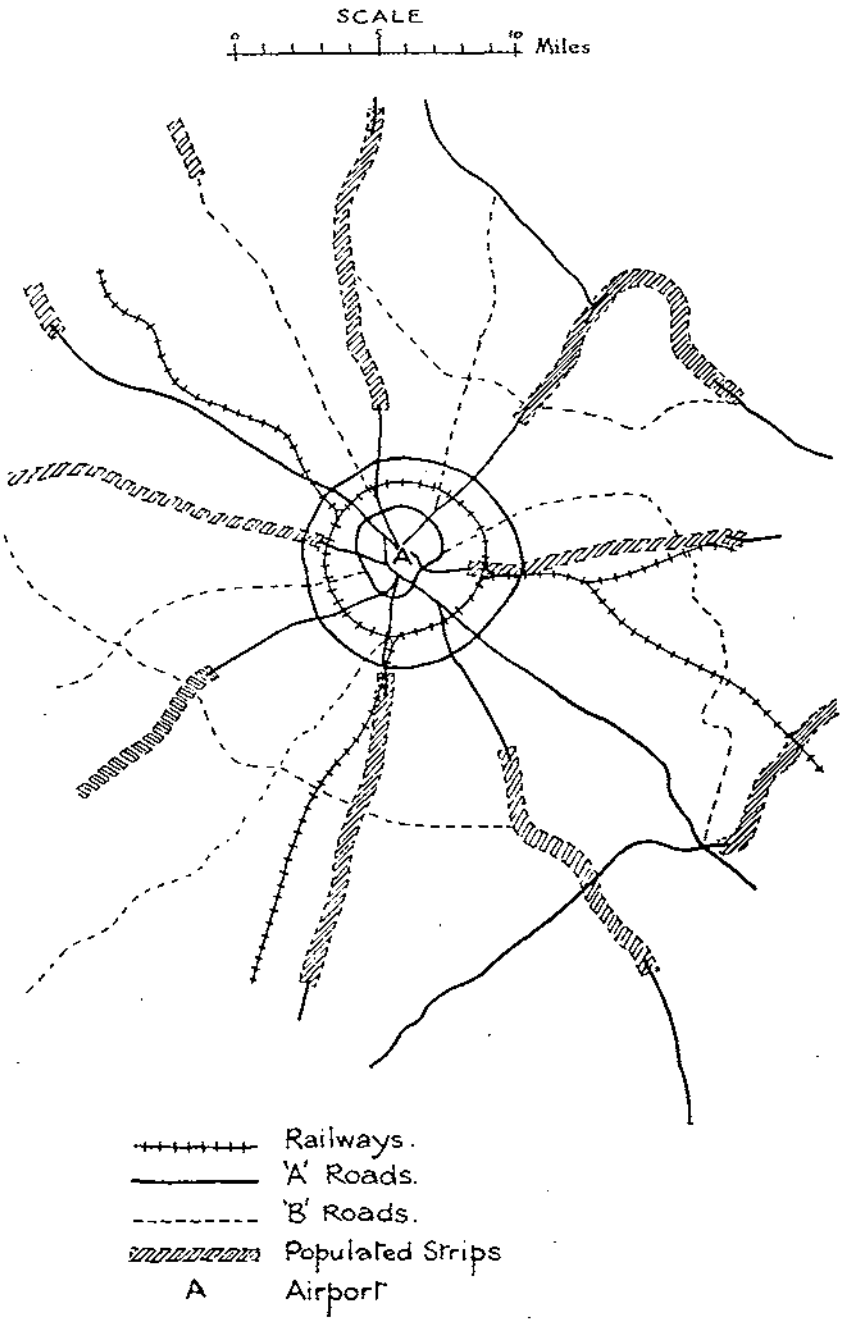
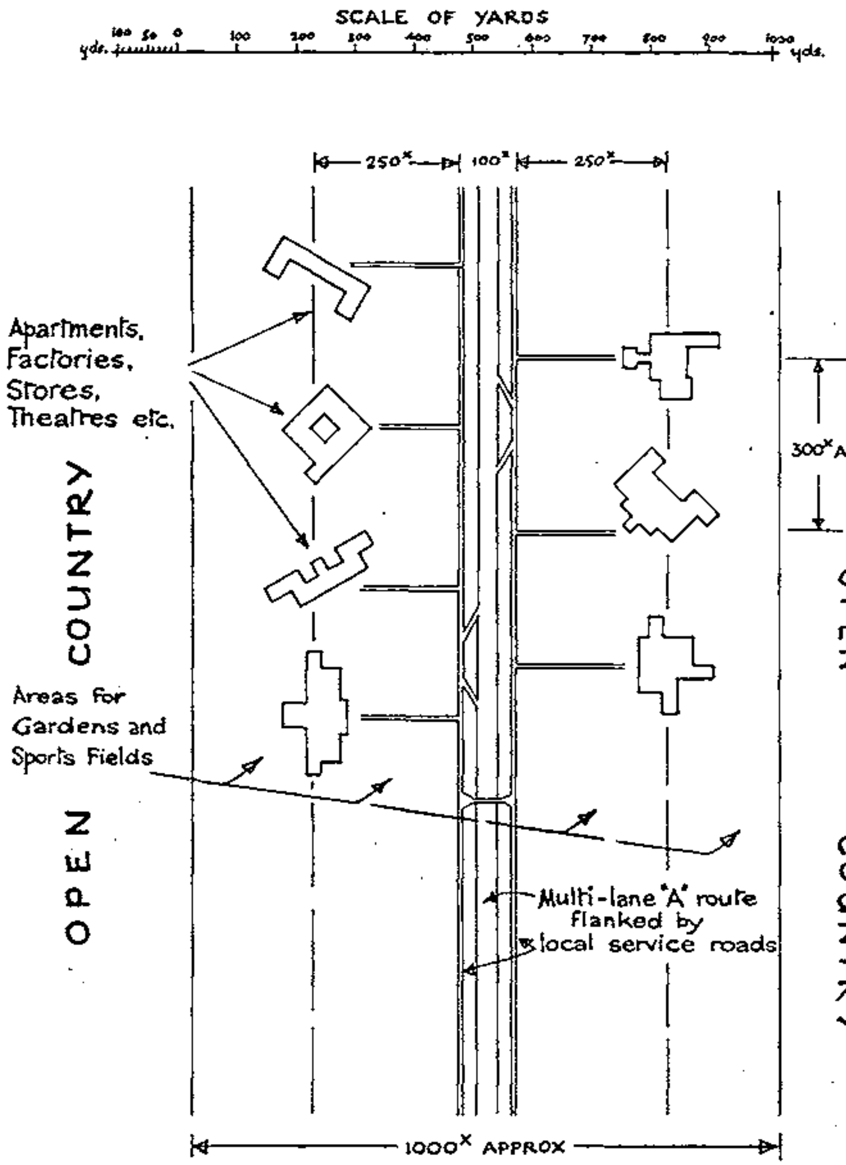


figure 4.
TYPICAL POPULATION STRIP



AVERAGE POPULATION PER APARTMENT BLOCK = 500.
DENSITY OF POPULATION PER LINEAR MILE = 6,000.

gardens throughout and the vista of magnificent buildings standing well back on each side is very impressive. Besides, there is the reverse side of the coin, in that you have *rus in urbe* wherever you go—the country is literally at everyone's back door. We also have the National Parks which are quite unspoilt. As regards the way of life, it has immense advantages, and is nothing like the existence in your city flats. We calculate that in your day at least 50 per cent of the national effort went into domestic chores—preparing meals, washing up, cleaning, shopping and so on. It is a mystery how you did any work at all—you did very little by our standards! In our homes, all this is centralized. A large choice of excellent food comes up in heated service lifts as ordered from the central kitchen staffed with expert cooks. And the debris goes down the same way to be cleaned and sterilized by machine. Room cleaning is done by a specialist staff with proper equipment, and is not often needed because there is nothing to create dirt. Heating is central and air is conditioned or fresh as you will (and incidentally the whole block can be sealed against gas or bacteria). As for gardens, everyone has a large balcony in front of his flat, which is big enough for a small garden. The big public gardens round the blocks are far better kept than any individual could manage, and include playing fields, swimming pools, children's playgrounds and every facility for relaxation or exercise. If anyone wants a walk in the country, it's only a few steps away. Private cars are kept in pens in each apartment. As petrol is not used there is no fire risk, and they are driven up and down a spiral way inside the block."

I was still not satisfied, and said:

"That is all very well, but there must still be people who prefer to live in the depths of the country. And what about the farmers? And our lovely old villages—are they all scrapped? May no one build a house away from the avenues?"

"The avenues in general house the former urban populations, and many other people prefer them for their convenience, particularly during their busy working lives. Farmers still live on their farms and we have taken particular care to preserve the country villages in outward appearance, though in the matter of convenience within they are quite transformed. But the villages are strictly limited in size and are mainly for the agricultural community. A few non-farmers do live in them, and may even build there, provided the statutory size is not exceeded. They consist, for the most part, of retired folk, who have priority in obtaining accommodation in villages.

"You may notice that a by-product of this system is a much more satisfactory traffic pattern. People go towards the nearest green centre for their recreation, and away from it if they are travelling elsewhere. This avoids the dreadful week-end traffic blocks you were accustomed to. Incidentally the civil airports are in the green centres, as they are convenient centres for travel. With vertical take off and landing, they take up little space, as you saw in Hyde Park. And now let's take a look at industry."

My companion again manipulated the switches, illuminating a mass of many-coloured dots spread like measles all over the map.

"Those are the main centres of industry, and the different colours show the various kinds. As you see, dispersion has been achieved, and this marries well with the dispersion of the population. The original reasons for concentration—nearness of labour and raw materials, and transport facilities—no longer operate in the same way, because transport is so much easier, and there is limited labour everywhere. There are certain specialized industries and undertakings, however, which have to be concentrated, and where they are vital, they are put underground. An example is the power stations, one of your most vulnerable features. Ours are all nuclear and deep underground, and they feed into a grid which is buried and so dense that it would be impossible to derange it appreciably. All transport is electrically propelled, so that the use of oil with its associated refineries and paraphernalia has quite gone out, except in small quantities for special purposes."

"What about ports?" I asked.

"Ah! That was one of the worst problems, but I think we have got it beaten now. We are practically self-supporting in food, but in war especially we should still have to import many things. The south and east coast ports are useful for continental traffic, but we do not rely on them. The west coast ports are small and very numerous, and Liverpool, Glasgow and Bristol are nothing like the size they used to be. Even so, there is a grave risk of almost total interruption in war, and to get over this we have our special trump card, the wonder of our age. I suppose you might call it a form of transatlantic Pluto."

"A pipe-line across the Atlantic? But you said oil was out."

"Not for oil. It's a good deal bigger and carries trains! The first one took fifty years to build. Soon we shall have half a dozen. They lie on the bottom of the ocean, but where they enter soundings they go underground into tunnels and emerge in deltas of exits inland. They are far too deep to be damaged by any foreseeable weapon."

"Good heavens! But at those depths and distances aren't the problems of pressure and ventilation most difficult and hazardous? And what about rescue, if anything goes wrong?"

"No worry. You see no one travels in them. The trains are unmanned and fairly small. The pipe is made of a light but very tough plastic. If there is a fault, the pipe can be raised and repaired by special ships and equipment, as cables used to be."

"And is there a channel tunnel?"

"We have had several for a long time now. They are valuable commercially, but militarily we do not set much store by them. They are too shallow to be safe. In war, we would not want supplies from the Continent, and we no longer keep forces there."

"And you have airlift?"

"Exactly."

"So you reckon you have all the answers?" I ventured.

"Don't mistake me," he replied, "An enemy could do us a lot of hurt. But we think it most unlikely that anyone would now try. Remember that we have a world lead in this matter, as we started planning so much sooner than anybody else. The result is that, whereas in the 1950s we were the most vulnerable country in the world, the boot is now on the other foot, and we still have the great tactical advantage of being able to concentrate our defences. Why, the Continent still has quite a number of old cities with sprawling built-up areas and concentrated industries, simply because they have never had the drive and tenacity to do something about it, even when we showed them the way."

My imagination still baulked at the immensity of the task of dismantling and replacing great cities like London. I asked my friend about this.

"It was indeed a staggering task, and took many decades to complete. From the outset, everything new had to conform to the eventual pattern, especially building. As the new ribbon areas became available, the central areas of the great cities were gradually evacuated, and the sites cleared. One of the first tasks was to widen all the 'A' roads and provide parallel local service roads. Once this was done, building was greatly speeded up and the laying and extension of main services was fairly simple and economical.

"At first, there was a popular demand to leave the centres of the old cities standing as they were, but empty, as a kind of sentimental relic. It was soon realized, though, that their deserted streets had a depressing effect, the buildings deteriorated rapidly and became the haunts of bad characters. So eventually only the most cherished and historic buildings and institutions were kept, and properly looked after. As for the railways, they were losing so much money and becoming so inefficient and unpopular, that something *had* to be done about them!

"Gradually the scene began to change and as the advantages of the new layout became apparent and popular demand for the new dwellings increased, private enterprise, which at first had been sceptical and unco-operative, began to take an enthusiastic hand, and the conversion went ahead at an ever-increasing rate. It was all over long before anyone had thought possible. The toughest nut was, naturally, industry, and we have not even yet attained an ideal situation."

"Have there, during this tremendous and prolonged transformation, been any major wars?"

"No total wars, though at first a long succession of local ones—in India, Arabia, Africa and South America—a continuation of what you used to call the Cold War. Some of these very nearly burst out into full-scale war, and on the last occasion, it was a close-run thing. I think myself that it was the fact that we had just completed our underground power system that tipped the scales in favour of peace. Since then, there has been no real threat."

"I would so like" I persisted "to get some idea of the time scale in all this. *How* long did it take—in fact what year are we in now?"

My companion looked at me rather queerly and said quietly, "There is a calendar behind you on the wall." I turned my head to look so that the wall spun round. But the calendar flashed past in a blur and the room went on spinning, faster and faster, till I felt giddy. I felt that dreadful falling sensation, and woke up with a shuddering start.

* * * * *

When the Committee met again next day, there was an animated buzz of conversation punctuated by laughter, but it was noticeable that a few members, especially the Minister of Town and Country Planning, looked a bit preoccupied. When the Chairman came in, they plied him with pleasantries and questions, but could get little change out of him as he sat there smiling blandly. Finally he spoke.

"What I suggest you do is to forget for the moment the difficulties and consider, each from the point of view of your own department, whether a state of affairs such as I have described, and its various features, would or would not be a desirable objective. And if not, why not?"

"But surely," somebody said, "this is going to take centuries, and any pattern we may conceive now might be utter nonsense by then. For instance war itself might have become an evil dream in the distant past, and then all our effort would have been wasted."

"The best way to make war a bad memory," replied the Chairman, "is to discourage people from waging it while it is not. And I doubt very much whether it will be a matter of centuries. Every step we take towards our objective improves our position and gives us a brighter hope. Besides which, there appear on the face of it to be many intrinsic advantages in this pattern, quite unrelated to war. For example, under our existing system, or lack of it, this island will soon be one large suburb, with no country at all. The great thing is to start, however slowly. If you don't like my dream-pattern, what *are* you going to aim at? We can't go on as we are."

"By the way," asked a military member "You said there had been no major war for ages. Did you gather what sort of armed forces were kept, if any?"

"I shall need a little time to dream up that one!"

SOME THOUGHTS ON NUCLEAR WAR

The Defensive Position

By "Centaur"

A GOOD deal of attention is being paid nowadays to the subject of field defences—that is to the design of individual defence works for present-day requirements; these include such protection as may be practicable against atomic weapons.

But little or no guidance has appeared on the effect of modern weapons on the design, or layout, of a defensive position.

It is sometimes said that atomic weapons will enforce perpetual mobility on an army in the field; that under the threat of being atomized, no sizeable unit or formation can afford to "stay put" for any length of time; and hence that no static, co-ordinated defensive will be possible. This view—with its suggestion of brigades and divisions buzzing around a theatre of war like wasps in a bottle is worth some examination. It is not the first time that the old horse "mobility" has been pulled out of the stable; he was tipped to win the war of 1914–18, but was well down the course at the end of it. Prior to 1914 we read in our *Corps History*,* "the general attitude . . . was that operations in a European war would be so mobile that the necessity for siege operations would be most unlikely to arise. One practise exercise in the attack of defensive works was held in 1907 . . . apart from this little attention was paid to the subject . . . the infantry had very scanty training in field entrenching . . . The elementary principles which should govern the layout and occupation of a trench system were unknown, and even the nomenclature had been forgotten . . . it was fortunate that those immediately responsible for the training of R.E. field units before the war, with the customary independence of thought of the R.E. officer, had not shared the official view . . . field unit commanders did their best within the limits of the restrictions imposed from above to prepare their units for the work they saw coming".

In this respect, how do we stand to-day? And, in the sphere of field defences, what work do we see coming? Let us, as they like to say in the B.B.C., hear what Jones, Brown and Robinson have to say about it. They are discussing the matter with a certain amount of that "customary independence of thought of the R.E. officer".

* * * * *

* *History of the Corps of Royal Engineers*, Vol. V. pp. 454-5.

Jones. Bicycles are what'll be wanted in the next war—the good old "bog-wheel"; or better still "stink-wheels", with little puffer engines on the back wheel; and a bit of cross-country performance if possible. What's the betting we shall have cyclist battalions like they had in 1914?

Brown. Why?

Jones. Because we're all going to be on the move all the time—so as to avoid being atomized. Everyone will be "flitting"—every day, or twice a day—and if everyone moves in trucks there'll be an unholy jam. Of course the big shots will flit in helicopters; but the R.A.C. will have to move in their A.F.Vs. and the gunners will have to cart their guns around. But for the P.B.I. and probably for you and me it'll be bog-wheels—pedal or puffer. Cycle troops could go through traffic jams like a dose of salts. I'm told that on August Bank holiday an auto-cycle can give a Bentley about half an hour's start from London to Brighton.

Brown. What about when we're on the defensive? Do we still go on with this milling around—flitting as you call it?

Jones. You bet we shall! That's just the time to keep moving. Only it won't be called flitting; "absquatulate" perhaps. All units will be in a perpetual state of "absquatulation".

Brown. Where to?

Jones. "A" to "B". Doesn't matter where "B" is as long as it's about ten miles from "A". Then just as the nuclear unpleasantness is exploding over "A" (which is where the opposition *thinks* you are) you'll be pedalling peacefully into "B" or brewing up there in your atomic foxhole. You see, directly the unit reaches "B" every man digs himself a hole; then he lays his bike flat across one end of the hole, spreads his groundsheet over it and shovels the earth back on top; and there he sits;—flash-proof, heat-proof and pretty well gamma-ray proof. So he'll be as safe as houses when this thing goes off over "A"—even if it's a bit off course.

Brown. While you're about it you might give him a small power-pick to dig his hole with; he could run it off the engine of his auto-cycle.

Jones. That's an idea! Jack up his stink-wheel and use a power take-off on the back wheel; why didn't I think of that?

Brown. You can't be expected to think of everything!

Robinson. Have you thought what would happen if "B" turned out to have been just vacated by, say, Corps H.Q.? It would be too bad if you arrived just in time to get the explosion intended for them!

Jones. That would strike a jarring note certainly. I think certain units, like important H.Qs. or batteries of "Honest Johns" which "attract" atomic missiles, will have to be considered as contaminating the ground. Each time they flit they ought to leave notices behind, with the date of contamination marked on them; those triangular affairs we used to have for gas warfare would do.

Robinson. Surely it's only units of that sort that might be affected; and even then only when concealment was impracticable. The ordinary unit—unless it's doing some vitally important task—won't attract atomic missiles—unless they become a lot cheaper than at present. I doubt if anyone's going to use an atom bomb to wipe out a battalion for instance, merely with the object of removing it from the Army List so to speak.

Jones. But usually a battalion would form part of a formation—which might well be a worth-while "extirpation target", if it could be wiped out in one shot. Obviously no normal degree of dispersion will foil an atomic bomb.

Brown. But a different sort of dispersion might. Just as you have traverses in a trench to localize the effect of a shell burst, so you might have traverses of ground (miles in extent) to localize the effect of an atomic explosion. It might lead to an organization of small groups, each group insignificant enough not to be "atom-worthy"; and the interval between groups would have to be sufficient to provide the "traverse". But each group could, itself, afford to be pretty well concentrated. In short, not general dispersion, but small concentrated groups in "atomic isolation". Of course the area occupied by say a Corps would be enormous; but aren't armies likely to get smaller and more mobile? You just can't afford to have men thick on the ground if they're liable to get the atomic treatment.

Robinson. How big could a group be without being atom-worthy and how large is an "anti-atomic traverse"?

Brown. Search me! But I suppose that when it's necessary someone will be able to make an intelligent guess.

Robinson. Well my guess is that the traverse or degree of isolation should be about ten miles in every direction—probably less in hilly country, and that the group couldn't be much larger than about two battalions or their equivalent.

Brown. I think that the group might have to be smaller than that if it were acting in an important rôle.

Robinson. Such as?

Brown. Such as occupying a defended locality in a major defensive position.

Robinson. Even then there must be a lower limit. I mean no one is going to use an atom bomb on a platoon post in any circumstances.

Jones. Nor can you hold a defensive position with platoon posts ten miles apart. I can't see that a static defensive position will be practicable in atomic war; if it's strong enough to be any use it'll just get wiped out when the time comes—or even before if it comes to that. Directly you see the opposition preparing a major defensive position in rear you give it the atomic treatment.

Brown. Then how is any sort of defensive line going to be maintained? After all, an army in the field must always, in the long run, either take ground, or give ground, or hold ground. And if it's going to hold ground, it must defend the line which divides the ground it holds from the ground it doesn't hold. But I agree that the old methods of defending such a line—with a continuous front of strongly held defended localities or divisional "boxes"—probably wouldn't work. It would, as you say, just invite atomization.

Jones. I think the line must be held by mobile troops, and minefields. It was done in the last war. 7th Armoured Division held about twelve miles of the Alamein Line for months on end. They swanned around in armoured cars or light tanks, keeping an eye on the minefields, shooting up any enemy patrols that appeared and then beating it.

Brown. That was desert. They couldn't have done it in close country. And when Rommel attacked in August, 1942, he got two *panzer* divisions and at least one infantry division through those minefields in one night; and then wasn't stopped till he got to Alam Halfa. And Alam Halfa was very much a static defensive position; the best part of an infantry division, plus the Corps artillery, all well dug in.

Jones. One atom bomb on Alam Halfa would have wiped the whole lot out.

Brown. Exactly. That's why, in atomic war a defensive line will presumably be thin, and lightly held—by men anyway. Mines galore if you like. But there must be *some* troops as outposts.

Robinson. A defensive position consisting only of a lightly held outpost line?

Brown. Yes—to start with anyway. It might be a line of small, well concealed, isolated and self-contained defence posts or forts. There would be minefields, round them and between them. These forts could be the bases or picquets from which patrols would operate. Helicopters might come in useful. If possible each fort should have a deep tunnelled shelter into which the garrison could go when ordered, and thus perhaps enable us to use atomic weapons at fairly short range, defensively. But even if the posts had only shallow ray-proof shelters, there would be a period during an enemy assault when we could use atomic weapons on the area of fighting and he could not; for his troops, at some juncture, would be in the open. That seems to be a considerable tactical advantage, to the defence, of atomic weapons; the side that's dug in is "quids in"—comparatively speaking.

Jones. But won't the little forts have been atomized before the assault starts?

Brown. Possibly—but it would be using a steam hammer to crack an egg. And for the sake of killing comparatively few men the enemy would risk creating physical obstacles against his advance. Remember how preliminary air bombing sometimes slowed up our advance in the last war; road junctions in towns and villages were often blocked with debris for weeks. That seems to be another advantage of sorts, of the A-weapon to the defence—its vast and indiscriminate power may embarrass the attacker. Of course the outpost forts could be subjected to non-atomic bombardment. But one would hope to conceal them, being small; and there would be a lot of scope for deception.

Robinson. Suppose the enemy succeeded in reaching or penetrating our defence line and then dug in? I suppose then we'd fight him at close quarters, and neither side would be able to use atomic weapons.

Brown. Neither side would use them on troops in contact I imagine. It might lead to the development of a close contact zone in which no one would have to bother about atomic protection; and in that case a much higher concentration of men would be possible. It could, I suppose, result in trench-warfare; a hundred yards between sides sort of thing, like in France in 1917.

Robinson. An old-fashioned war in the middle, with atomic missiles going overhead in both directions! Anyway, to get back to field defences. If your view is right, a major defensive position will be minefields and more minefields; very small defended localities, in "atomic isolation", to include some deep tunnelling; and trench warfare of sorts as a possible development.

Brown. Not forgetting the local defence of every small group in "atomic isolation" in rear; and also some sort of ray-proof shelter for every man. That might well be the biggest commitment in engineer stores; for, as we are beginning to realize, constructing any sort of roof by improvising with "local" materials is easier said than done.

Robinson. But for atomic flash and heat—which some of the experts seem to think are the chief dangers—almost any sort of roof will do. Even an umbrella is fairly effective.

Jones. Ye Gods! Bicycles and umbrellas—in this age of scientific progress.

Brown. And the spade. Don't forget the spade-work; you've got to dig the hole—and probably revet it—before you can put a lid on it. We've almost forgotten how to dig by hand; but it looks as if that's the way it'll be—for everyone.

ANALYSIS OF AN ARMY CATCHPHRASE

By MAJOR R. A. LINTON, M.A., A.M.I.E.E., R.E.

"THERE are always several equally good ways of doing a job", states the old army saying, and as a result of this assertion one is urged to waste no time in choosing a plan.

It is curious that the British Army should accept this teaching unquestionably, whilst elsewhere people adhere to the teaching that "there is only one best way of doing a job, and one should always strive to find this best way".

The two sayings are incompatible, but one cannot go so far as to say that either of them is wrong. One finds, the more closely that one examines them that each is suited to a definite set of circumstances, and that each will bring success in its own particular setting. In a contest it follows that where one succeeds the other will fail, and it is therefore important to be able to recognize which teaching should be adopted in a given situation.

Let us then examine in detail certain problems, and in doing so let us try to evolve rules to guide us in applying these two conflicting principles.

As a first example take the case of a company commander planning a counter attack. Let us consider his situation at three different times: P=the present moment, $P+4$ hours, and $P+8$ hours. Our company commander will consider three different plans, (I) a right flanking attack, (II) a frontal attack, and (III) a left-flanking attack. Without making any reconnaissance he rates the efficiency of these plans as follows: (I) 100 per cent, (II) 80 per cent, (III) 60 per cent. Let us assume that if he were permitted four hours in which to reconnoitre, he would discover that in practice the efficiency of plan I would only be 50 per cent of his original forecast. As a further factor we assume that at $P+8$ artillery support can be obtained, thereby increasing the efficiency of all plans by 50 per cent.

We now assess the increase in the enemy's power of resistance as follows. At $P+4$ he will have dug in and his resistance will have been doubled, at $P+8$ he will have been reinforced and his resistance will have been quadrupled.

We can tabulate our alternatives in terms of efficiency per cent as follows:—

			$P+4$	$P+8$
At time P			($=\frac{1}{2}$ P due to enemy digging in)	($=\frac{1}{2}$ $(P+4)$ due to enemy reinforcement $+50\%$ for artillery support)
	Apparent	*True*	*True*	*True*
I	100%	50%	25%	$18\frac{3}{4}$%
II	80%	80%	40%	30 %
III	60%	60%	30%	$22\frac{1}{2}$%

It is easy to see from the above that if our company commander had counter attacked at P hours, and had chosen plan I, he would have achieved 50 per cent efficiency. If he had waited until $P+4$, the best he could have hoped to have achieved would have been 40 per cent, and he might only have obtained 25 per cent. Thus we see in figures a basic military concept: "A fool who acts promptly will do better than the wisest man who delays". This of course is the justification and the purpose of the military catchphrase.

Having thus established that in the above military problem the army catchphrase produces results superior to its civilian counterpart, let us examine the two sayings more deeply.

It is at once obvious that the military catchphrase is less true than the civilian teaching. In the above example plans I, II and III are by no means equally good, and it requires little imagination to realize, that if one is going to measure efficiencies down to three places of decimals, the chances of even two plans being "Equally good" are remote. Three or more alternatives have an infinitesimal chance of being equal, and in the vast majority of problems, when all factors have been evaluated, one plan will normally stand out as being the best.

In order to illustrate the value of the civilian teaching let us take as an example a technical military peace-time problem, chosen to be almost an opposite extreme to the first one.

An officer is asked to produce a plan for improving the efficiency of a W.D. power station.

After a month's reconnaissance and calculation he narrows down his proposals to three alternative systems, approximately estimated as follows:—

A. Will cost £20,000, and will increase efficiency by 1 per cent. The life of the machinery will be 15 years.

B. Will cost £40,000, and will increase efficiency by 2 per cent. Its life will be 15 years.

C. Will cost £100,000, and will increase efficiency by 4 per cent. Its life will be 20 years.

Assuming that the annual bill for the electricity supplied is £250,000, a saving of 1 per cent amounts to £2,500.

In order to assess the value of the three schemes consider the financial position at the end of the life of the machinery, i.e., in fifteen years' time for schemes A and B. And in twenty years' time for scheme C. Take interest on capital at 3 per cent.

Then we have:—

Scheme A

Saving of £2,500 per annum for 15 years		£37,500
Less cost of machinery	£20,000	
Less 3% on £20,000 for 15 years ..	£9,000	
	£29,000	£29,000
Net saving		£8,500

$$\text{Saving per annum} = \frac{£8{,}500}{15}$$

$$= \text{Approx. } £600 \text{ per annum}$$

Similarly *Scheme B* shows a saving per annum of approximately £1,200, and *Scheme C* over a period of twenty years shows an annual saving of approximately £2,000.

We see therefore that this problem is readily calculable into one simple standard of comparison, viz., money saved per annum. And scheme C gives the greatest saving.

Very many problems, which at first sight appear to offer numerous alternatives, and whose solutions are apparently overshadowed by imponderables, can be reduced to one or two simple considerations if they are correctly analysed. And wherever time allows they should be analysed down to a point where the issues at stake are clearly and simply set out.

The above problem can be very much complicated by imagining that the power station concerned is at a place like—say—Fayid in the Canal Zone. Here a life of twenty years might well be longer than the life of the base. What plan is then likely to prove the best?

If such a hazard is stated in the instructions given to the officer preparing the schemes, he must present his information differently. In this example it would be best done by drawing graphs showing the financial state of each scheme annually from zero years to the end of the life of the scheme. Whoever has to take the decision can then weigh the information displayed by these graphs against the other considerations which will affect the decision.

The guiding principle however, in all questions of this kind, is the civilian teaching: "There is only one best plan and one must strive to discover it."

It is apparent, from the above examples, that the army catchphrase is applicable only to situations which are rapidly deteriorating, or in which time is particularly valuable. It is a philosophy for use during crises where events are moving swiftly, and where the tables can be turned by prompt action.

War itself is a crisis, but it is not one long crisis. It usually moves in fits and starts, periods of furious activity bursting upon one suddenly, and then petering out into weeks and months of boredom and routine. The military catchphrase is only applicable to decisions taken in the heat of the battle. If its philosophy is carried over into static or semi-static situations, waste and inefficiency ensue.

In the period of preparation for war only the best is good enough. The idea that any of several plans will serve leads to slackness. In its wrong context the army catchphrase is a philosophy of carelessness. It shields the incompetent and frustrates the gifted. It is used to blunt the inquiring mind, and it spreads a uniform level of mediocrity.

In its correct context it leads to prompt bold action. It teaches a man not to hang about once the fight has started, but to wade in and hit hard and often.

The civilian teaching is hopeless in a crisis. One cannot wait to reason out the best line of action in a swiftly moving situation. By the time you have worked it out the situation has changed and you have to start thinking all over again.

But when there is no great hurry, and you have time to investigate and reason out a plan, the civilian teaching comes into its own.

There is a tendency however, in the British Army to make unnecessarily careless decisions in times of peace. The practice starts perhaps round the sand table, where the young officer attends a tactical exercise, and listens to his superiors arguing out a particular problem. Each syndicate leader is convinced that his plan is the best, and the directing staff eventually close the discussion by tactfully saying: "Well there are no doubt several equally good ways of doing the job." And this well-worn quotation is so steeped in tradition that it is accepted by all unquestioningly.

The young subaltern then goes out into the big wide world, and when he is faced with a choice of plans, about which there is some dissension, he picks out the one which he thinks best, and he quells argument with the old familiar phrase which he learnt from his superiors at the sand table. Thus a rotten job is frequently done, when a little careful analysis would have revealed to the responsible officer which plan really was the best.

I write with feeling upon this matter, for time after time have I been employed on ill-conceived, wasteful plans. And when I have protested about some particularly appalling feature, my arguments have been dismissed with the traditional remark that "there are no doubt several equally good ways of doing the job".

I hope I have convinced the reader by this time that it is not true. There is only one best way, and it is the duty of every officer to try and find it.

The army catchphrase may well be costing the taxpayer hundreds of thousands of pounds a year.

I would suggest therefore to the conscientious reader that he carry with him always a clear picture of the conditions under which the two teachings apply. It is a hard struggle to try and get the best plan adopted in every circumstance. The key to the situation is to analyse a problem down to the last detail, and then to present the facts in such a way that even a lazy man can see clearly which plan is the best.

Let me then illustrate the foregoing with a lesson from real life.

One of the quickest thinkers I have ever met was a young soldier who was a successful amateur boxer. He did not look particularly strong, and he never appeared to be hitting very hard, but his fights were usually stopped in the second round with his opponent knocked into a groggy condition. The secret of his success was that he never wasted a punch. His every punch was accurate, and it took its toll. He used no bluster, no show, relying on his brain to direct his strength only where it would do some damage. Here was a man whose success was due to accuracy and economy of effort. Almost every blow he struck was the result of a right decision.

All great achievements in this world are the result of a long series of right decisions. The evolution of the Spitfire, the musical show *Oklahoma* and the conquest of Everest, all started off with certain major decisions, which led to a multitude of detailed decisions. And because these decisions were predominantly right the over-all plan succeeded.

Let me therefore end with another catchphrase to counteract some of the damage done by misapplication of the army one: "When time permits always strive to find the best way to do a job."

CORRESPONDENCE

ARMOURED FIELD ENGINEERS

From
Lieut.-General Sir Giffard le Q. Martel, K.C.B., K.B.E., D.S.O., M.C.
Bulford Lodge, Heatherside,
Camberley, Surrey.

1st November, 1954

To The Editor,
The *R.E. Journal*.

Dear Sir,

After the first World War, I carried out a considerable amount of development work at Christchurch to ascertain, in what ways, armour and mechanized power could be used by field engineers to assist them in carrying out their duties. The R.E. tank was produced and we designed many pieces of equipment to enable this tank to carry out such duties as bridge laying, demolition of obstacles, sweeping a way through minefields, and these were all carried out from behind the protection of armour plate. The tank was also used for drawing a Fowler plough for grading and also for cable burying by using a mole drainer. Air compressors were, of course, to be carried for use on road work and in boring holes for demolition work. We set out to use mechanical power in every possible way in the army, as this was what was happening in many ways in civil life at that time.

In 1919 I wrote an article which appeared in the *R.E. Journal* in October 1920 and described all this work. The article explained that as the army became more and more armoured, an increasing proportion of our field engineers would have to be armoured to carry out their duties.

Unfortunately all this work was forgotten in a few years after the first World War and no steps were taken to produce armoured field engineers, even on paper. In the middle of the second World War, however, all these ideas were reinvented and very much in the same way as in 1919. The R.E. tank was reintroduced and called the A.V.R.E. It was interesting to see all this work coming in again after a lapse of a quarter of a century. It was considered to be too late at this stage to introduce armoured field companies into the divisions and a new formation—the 79th Armoured Division—was formed to contain these R.E. armoured units and certain other special units. Under the command of Major-General Sir Percy Hobart they carried out splendid work and proved to be just what was required.

After the second World War and as a result of the experience of the 79th Armoured Division, it seems obvious that the original proposals made from Christchurch in 1919 should have been put into effect. A proportion of the field engineers in all formations should have become armoured field engineers, but little progress was made in this direction.

We did, however, produce a unit after the war which was to continue the development of this work of the armoured field engineers. This unit has done splendidly in developing this work both for infantry and armoured divisions.

It is now accepted that greater mobility will be demanded with the advent of atomic weapons. Perhaps a larger proportion of armoured divisions will be needed. The field engineers will have to be speeded up accordingly. It would seem that two of the Squadrons in a field engineer regiment of an armoured division should become armoured field squadrons. In an infantry division perhaps it would be better to have only one armoured field squadron. The Corps troops might also include an armoured field squadron.

The field trials in connexion with this work should, of course, be carried out by these field units, but a small training unit would be needed to carry out the experimental work.

Yours truly,

(signed) G. le Q. Martel,

Lieut.-General.

B.R. or B.M. ?

From:—Brigadier T. I. Lloyd, D.S.O., M.C.

Room 242,

The War Office,

London, S.W.1.

13th January, 1955

The Editor,

The *R.E. Journal.*

Dear Sir,

Last June you were kind (and progressive) enough to publish my article "B.R. or B.M.?" and in September your correspondence pages featured a reactionary counter-view, the letter in question being, in my experience, typical of the attitude of people who seek to excuse themselves from looking really deeply into this question of converting our railways into roads.

I should be grateful for space to enlarge on just one subject raised by your correspondent: *vehicle depreciation.*

A bus in city service lasts for about twelve years: its annual depreciation therefore appears commendably low. But there is another aspect of the matter. The average bus covers 30,000 to 40,000 miles a year; it has a "life" of the order of 400,000 miles. This life has been, as it were, built into the vehicle (though it must be sustained by maintenance), and it determines in advance the maximum possible gross earnings of the vehicle. In striving after this fixed, limited sum, the owner ordinarily has to pay his men for twelve long years. The manpower backing is approximately six per bus, say £3,000 a year. If the owner could get that 400,000 miles out of the vehicle in three years instead of twelve he would save £27,000 in wages.

Your correspondent was perturbed to arrive at the conclusion that a vehicle might be worked to death in two years on the converted railways—which would save a further £3,000.

Again, as in my original article, I have had to deal very broadly with intricate matters within a complex subject; but perhaps this little arithmetical sum will serve as an example of the way in which the more one looks into the scheme the more worthwhile it seems.

Finally, is there not a prophetic knell about the sobriquet *Iron Horse*!

Yours faithfully,

T. I. LLOYD.

BOOK REVIEWS

THE FIRST COMMONWEALTH DIVISION

By Brigadier C. N. Barclay, C.B.E., D.S.O.

(Published by Messrs. Gale & Polden. Price 25s.)

Ever since the ugly attempt by the U.S.S.R. to blockade Berlin, the U.S.A. have been absolute for curbing Communism. This policy of firm resistance to the moral and physical pressures of the Communist States has been the most hopeful political feature of the last seven years. It had no counterpart in Europe between the wars, when Hitler, bullying and grabbing without effective restraint, was suffered to set the stage for World War II. This time, at any rate, the world situation is not being allowed to slip.

Foiled at Berlin by the great air fleets of the U.S.A. and Great Britain, the Communists then sought a quick success in the cold war by the seizure of Southern Korea. This dastardly plan also came to grief. The Korean War cost the Communists the total loss of the North Korean army and 1,800,000 casualties. Unless they are very different from the ordinary run of allies, this colossal political and military failure must have certainly created difficulties between Communist China and the U.S.S.R.

The U.S.A., the most powerful of the United Nations of the West, were again the prime cause of the Communist discomfiture. Within a few months, they deployed a great fleet, dominating air forces and the equivalent of about twelve U.S. divisions in the Korean theatre of war. With these and other forces sent by the United Nations, they restored the situation so completely that the Communists were finally glad to agree to a singularly barren armistice. The cost to the U.S.A. was heavy. In June 1953, just before the end of the war, the U.S. casualties numbered 136,862, of which 24,386, or about 1 in 6, were killed. These losses, which are higher by 30,000 than those incurred in the total defeat of Japan in the Pacific, reveal the greatness of the American sacrifice in Korea and the cause of a hostility to China, which some people still find difficult to understand.

Such was the rough balance sheet of the mischievous Korean War in which the Commonwealth, although heavily committed elsewhere, immediately participated to the utmost of its capacity with aircraft, ships and troops. The Commonwealth Division, gradually built up from the brigade groups as they arrived, deservedly made a great name for itself, for the intensity of its ordeals in battle was just as great as those of the highly tried U.S. divisions.

Brigadier Barclay has therefore done well to produce so quickly this clear and comprehensive account of the exploits of the division. He points out in an excellent preface that his chief purpose is to write for Commonwealth participants in the war, who will thus have a reliable account of it long before official historians can put pen to paper. Field-Marshal Lord Alexander, who writes a foreword, and the author himself both draw particular attention to the composite structure of the formation, which was made up from six different Commonwealth nations and which thus added something new and splendid to our common history.

As is proper in such a reputable work, complete orders of battle give the names of commanders, staff officers and units, who at various times took part in the campaign. Nor does Brigadier Barclay fail to make some shrewd observations in retrospect on the military events, which he describes so well. The maps, reinforced with sketches, are most adequate and the photographs are well chosen.

This first chronicle of a novel and triumphantly successful experiment in Commonwealth relations will assuredly find favour, not only with the former members of a now world-famed division, but also with all those whose business or pleasure is to study war. B.T.W.

AN INFANTRY COMPANY IN ARAKAN AND KOHIMA

By MAJOR M. A. LOWRY

(Published by Gale & Polden, Ltd. Price 10s. 6d.)

This book of about 130 pages gives a very good idea of what life is like in an infantry company in war. It covers the period between December, 1943, and May, 1944, when the author was evacuated, sick, from Burma. Throughout this time he commanded "B" Company, 1st Battalion The Queen's Royal Regiment. The book was originally written as a diary, in a series of exercise books provided by his batman. (This is not actually mentioned, but the author has told me since.) It gives a matter of fact account of day-to-day events.

You want to read this sort of story as an antidote to the "high-level" stuff by cabinet ministers and commanding generals. It shows how, in the end, battles are won "by the goodwill of the private soldier". You see the company commander "giving the chaps a talk on the general situation", or disposing his platoons on the forming-up point before an attack, or dodging shell fire while trying to get to Battalion H.Q. for an Order-Group. You see him and his C.S.M. throw grenades at a Jap patrol, and you read how the C.S.M. of "C" Company, who was standing near him, was killed by a sniper just before he himself shot the sniper. It is all very modest and factual.

As you read it you sense the indomitable perseverance, courage and good humour of the cockney soldier: How one man—Corporal Porter—"seizing the Bren gun charged the (Jap) post and knocked out all the enemy in it. But in doing this he himself was killed"; or the conversation overheard between two privates when the division was surrounded.

1st Private: Seen the nooze mite? Churchill says 'e is wotchin 'ar front wiv intense int'rest.
2nd Private: "Yus?"
1st Private: Well, wot I sez is, that he ain't wotchin' 'ar bleedin' rear.

You get an idea of the perpetual care the good officer takes of his men, of his many anxieties, of his lack of sleep, of his discomforts and the professional competance he needs for his job. You realize, too, the great debt we owe to the Unknown Warrior—but with this difference: he is not unknown to his company commander.

Strictly speaking, this is not a good book. There is no drama, there is not much literary skill—there are, in fact, a few grammatical errors—and, of course, the "big picture" is totally lacking. But none the less, one ought to read it, to be reminded of the trials, tribulations and triumphs of the regimental officers and men who do most of the dirty work in war.

M.C.A.H.

FIVE VENTURES. IRAQ–SYRIA–PERSIA–MADAGASCAR–DODECANESE

By CHRISTOPHER BUCKLEY

(Published by H.M. Stationery Office. Price 10s. 6d.)

This book is the latest in a series written for the Government and designed to be a short Military History of the second World War. The book deals with five of the lesser campaigns of the war, fought by comparatively small forces, but in each case with much at stake.

The campaign in Iraq became necessary, to secure our oil supplies, after Rashid Ali, with his markedly pro-German leanings, came to power in April 1941. That in Syria, a few weeks later, was to prevent the formation of German bases among the Vichy adherents in that country. The third venture, which finally destroyed German influence in the area between the Mediterranean and India, was in Persia and secured the vital supply route to Russia, via the Persian Gulf. Early in 1942, when the Japanese armies were spreading so alarmingly over the Far East, another campaign became necessary against the Vichy French in Madagascar, to deny the use of the harbour at Diego Suarez to the Japanese Navy. The stake in the last venture, that in the Dodecanese, was the possible entry of Turkey into the war on the side of the Allies, but lack of sufficient forces and a masterly counter stroke by the Germans doomed the campaign to failure.

These stories, told from the military rather than the political point of view, are of absorbing interest and are in enough detail for most readers. The only criticism that might be made is that the maps, which are good in themselves, cannot be folded out from the text and thus much turning back and forth is necessary. P.L.N.

A DIARY OF THE CRIMEA

By GEORGE PALMER EVELYN, edited, with a preface, by CYRIL FALLS

(Published by Gerald Duckworth & Co. Price 12s. 6d.)

The invention of the "electric telegraph" enabled the British public to follow the course of the Crimean war day by day in the newspapers in a way, that was new to history. The theatre of war and the armies engaged were small, so that even the inexperienced could readily understand what was happening. Thus the whole of Britain read with passionate interest of the unending gallantry of its troops, which had to offset the appalling incompetence of almost all the responsible authorities. The memory of the "soldiers' battles" of the Crimea has, indeed, outlived that of other more important national adventures. Mrs. Cecil Woodham-Smith has lately honoured the centenary of the Crimea with *The Reason Why* and *Florence Nightingale*. Close on the heels of those two notable books, there now comes this fascinating diary of the Crimea. It was written by a George Evelyn, who was a retired rifleman and a descendant of John Evelyn, the famous diarist of the seventeenth century. Although apparently somewhat haphazard in his spelling, the ex-rifleman wrote good robust prose. It would, for instance, be difficult to improve upon his disapproval of "the generals, who merely put their men in front of the enemy's cannon and told them to march on."

The book is admirably edited and prefaced by Cyril Falls whose footnotes are few but good. One of them tells how General Sir George Cathcart was killed in a muddled episode at Inkerman, his last words being "I fear we are in a mess". They seem to sum up the whole war in a sentence. *A Diary of the Crimea* will delight everybody who reads it. B.T.W.

HIS COUNTRY WAS THE WORLD, A STUDY OF GORDON OF KHARTOUM

By CHARLES BEATTY

(Published by Chatto & Windus. Price 21s.)

The author, in a few lines of preface, says that it is his object to allow Gordon to emerge as a lively person: in that, with the help of a biggish bibliography and his own lively imagination, he may be said to have succeeded and produced a fairly readable book—a bit verbose and irrelevant in a few places, but on the whole a just and generous assessment of his subject.

It is a pity that in his text he quotes Chaillé-Long and his book *My Life in Four Continents*. Long was one of a batch of American officers then serving in the Egyptian Army, whom Gordon picked up in Cairo and took with him to the Equatorial Provinces but later had to dispense with. In Long's book, written many years after, lies the *fons et origo mali* of the ill-founded slander of Gordon's addiction to drink.

Mud, by whomever thrown, will stick—Lytton Strachey, with his facile but sometimes inaccurate pen, resuscitated the story of Gordon's addiction in his *Eminent Victorians*, written in 1918 during the first World War: and as recently as 1953 an *ill-written* book by two Hansons, baited with the title *Gordon: the Story of a Hero*, repeated all the old insinuations about drink, the familiar story of the nobody snatching at any stick to belabour the somebody.

Our author, Mr. Beatty, happily does not suffer from these morbid traits of iconoclasm. He writes gallantly and displays great thoroughness and acumen in winnowing the grain from the chaff in all the authorities he has studied. His book is a full biography in some 290 pages, and thus touches upon each part of Gordon's varied life: a useful chronology and three essential maps have wisely been included. E.E.B.M.

ENGINEERING METALLURGY

By DR. E. M. H. LIPS

(Published by Philip's Technical Library, Holland, and distributed by Cleaver-Hume Press Ltd., London. Price 32s. 6d.)

Dr. Lips has written a book which might well be entitled "Metallurgy Made Easy". He opens the book by showing the student the various methods for testing materials (i.e., for hardness, toughness, ultimate strength, etc.); the descriptions are well illustrated and the reasons for making such tests are concisely set out. Then follows a section on the mechanical properties of metals in which the phenomena of fatigue and creep, together with the effects of irregular shape on strength are discussed.

The author devotes two chapters to a description of ferrous metals. He assumes an initial knowledge of the manufacturing processes involved, and leads the student on to the chemistry and physics of ferrous metals. He explains the crystalline structure of the various types of iron and how this may be altered by heat, and then shows how irons and steels for specific purposes and strengths are produced. The section on tool steel is particularly interesting. Non-ferrous metals are treated in a similar way, whilst a section is devoted to describing the methods of working such alloys. A good proportion of this last chapter describes the metals aluminium and magnesium, together with their more common alloys.

The last two chapters cover heat treatment, methods of working metal and jointing metals. The importance of stress relief in castings is brought out, and the methods of hardening and normalizing irons and steels by heat treatment are well described. Control of grain size is somewhat sketchily covered.

The book is translated from the Dutch, and apart from a few minor printer's errors, is well laid out and is very readable. It is recommended for students studying to the level of a Higher National Certificate; but for anyone interested in understanding the fundamentals of metallurgy it can also be recommended. W.A.H.

COST ACCOUNTING AND THE ENGINEER

By KENNETH B. MITCHELL, A.C.W.A., Aff. I.W.M.

(Published by Iliffe & Sons Ltd. Price 10s. 6d.)

This book of 124 pages and twenty-six well drawn figures explains, in a way easily understood by production engineers, the advantages obtained in manufacturing establishments by reliable systems of cost accounting and budgeting and budgetary control. It is unfortunate that the techniques of cost accounting are not more widely understood and applied, and this book attempts to bring costing to the notice of engineers while subordinating those questions of cost which tend to be academic. Mr. Mitchell makes the subject interesting and at times fascinating, and demonstrates its importance to industry.

Part I relates to Cost Accounting. As competition increased the need arose for intelligent price fixing and progressive cost reductions by eliminating wasteful practices. The principles of cost accounting were brought into being as an absolute necessity for the economical operation of an establishment. Costing is an aid to management, but careful analyses by cost accountants will be of little use unless the senior officials are prepared to take action on the basis of the cost accountant's findings.

There are two major factors in Costing. The first is that it is necessary for both management and supervision to provide accurate and continuous information for the cost department. The second factor is that the management must act promptly on the costing information received.

Chapters are devoted to accounting for materials; accounting for labour; control of overhead expenses; applying overhead expenses to production; final costing and presentation; the influence of fixed and variable costs; and costing by standards.

It is emphasized that statistical reporting must be done frequently and always very promptly even perhaps at the expense of some degree of accuracy, for a costing report, a few shillings out but presented when required, is of more value than a report received too late, but absolutely accurate.

Part II deals with Budgeting and Budgetary Control. Many financial failures in manufacturing establishments have been undoubtedly due to lack of knowledge and financial appreciation by managements who instituted policies beyond the financial strength of their companies. The installation of a budget plan assists to uncover hidden sources of loss, and points to the departments where corrective action is most needed. It assists good management to become better, more objective and able to control a situation with greater effectiveness. The budget plans the income and expenditure in relation to the desired level of profit for an industrial organization, while the budgetary control indicates the controls which should be effected throughout the budget year.

This book should be read by all Sapper officers who may be called upon to control engineer workshops or productive installations. W.B.C.

TECHNICAL NOTES

CIVIL ENGINEERING

Notes from *Civil Engineering*, September, 1954

Prefabricated Construction

The first of two articles appears this month, in which the author describes the progress achieved, on the Continent, in this type of construction. Prefabrication of components, through closer control of the concrete, allows thinner sections to be used, thereby effecting a saving in materials and dead weight. A better finish at lower cost is also achieved. In the past, prefabrication in the building world has been confined to such articles as fittings and floorings, but in Switzerland, recently, a number of large buildings have been either wholly, or partly, constructed from prefabricated elements. Such a building was a twelve-storey block of flats, for which site work started in April, 1952, and the roof was completed in early October of the same year. The quickest rate of building achieved on this job was one storey in four days.

Erection is naturally dependent on efficient cranes, and in order to realize the savings in cost and time, inherent in the system, thorough planning from the production factory, through the transport and handling systems to the site organization is essential. Much depends on the reduction of handling charges to the minimum.

Quicker erection times call for a similar speed up in other trades, and consideration must be given to prefabrication in the heating, ventilating, electrical and other trades. The greater precision obtained by prefabrication of the main structure allows similar action to be taken in these allied trades. Here lies the secret of lower costs.

Although the importance of this type of construction has been realized in the past, it has been confined mainly to small works. Its successful application to large structures is of considerable importance to both civil and military engineers.

No Fines Concrete

Long-term tests have recently been carried out at Belfast University on the strength of no-fines concrete. The article describes the test procedure, where an 8 : 1 mix was used; the size of aggregate was limited to that passing a ¾-in. mesh and retained on ½-in. mesh. The water cement ratio was 0.43. Tests were carried out over a period of seven years and, on hand tamped specimens, the following average stress values were attained.

Age in Months	Compressive stress lb./sq. in. on 6-in. cubes
0.5	734
1.0	821
18.0	1,170
87.0	1,532

Short Reinforced Concrete Columns

Part I of a series of articles by Dr. S. Mackey describes tests carried out on short reinforced concrete columns in order to gauge the effect of slenderness ratio on strength. From past investigations the column strength of unreinforced short columns (i.e., where $L/D < 15$) has been accepted as 0.7 times the corresponding 6-in. cube strength. Justification for applying this factor to reinforced columns has not, according to the writer, been borne out by further tests, and he argues that the factor should vary with the slenderness ratio. Unfortunately, the tests so far carried out, though confirming the writer's opinions, are not sufficiently comprehensive to determine a definite range of factors. The article is to be continued.

Notes from *Civil Engineering*, October, 1954

Prestressed Concrete

Underlining the increasing importance to the structural engineer to-day of prestressed concrete, are two articles describing contemporary work. The first concerns a new road bridge in South Wales of 60 ft. clear span and 16 ft. carriageway. The superstructure consists of eleven precast, post tensioned, prestressed concrete **I** beams, nine of which are set close together under the carriageway; the remaining two are set one on each side and support the outer edges of the two reinforced concrete slab footwalks. These girders were delivered to site in 8 ft. elements, and after assembly were post tensioned *in situ*. Prestress was applied by the Freysinnet system. Transverse prestress was also applied at top and bottom of the girders, the former being done first. Owing to site conditions, assembly and tensioning were somewhat difficult, but in view of the S.M.E.'s. interest in a similar type of construction, it is worth recording that this bridge was constructed, including cable tensioning, by local labour quite unskilled in this type of work.

The second article deals with an unusually shaped structure for the Bank of England printing works. The main hall has an arched roof based on a mathematical curve. The arches were made of precast segments, post tensioned *in situ* by the Freysinnet system. Owing to the shape of the curve, the location of the prestressing cables is unusual.

River Defence Works

Based on a type of repair work already found to be satisfactory on the River Po, the South Wales River Board have initiated protection works on the River Tawse. Gabions, forming the backbone of the defence works were prefabricated close to the site and then positioned by crane. The advantage of gabions over a solid concrete wall is well illustrated in two photographs showing:—

(*a*) a concrete groyne badly undercut and therefore useless;
(*b*) a gabion, deformed and therefore resisting further undercutting.

The claim in the article that the use of gabions is of a pioneer nature in this country sounds somewhat naîve to a Sapper!

Vibration on Soils

This second instalment concludes some notes on the effect of vibrations on soils, started in the August issue. The author considers the effects that pile driving or the use of explosives may have on adjacent structures, whether piled or not. He shows how clays and silts compact under vibration, and explains the possibilities of "quick sand" forming in silt. The effect of settlement may not be immediately apparent especially in clays where the escape of water is slow, and the writer desribes various examples of settlement and their causes. An equation and graph are derived from which the maximum safe charge may be calculated, should resort to explosives be necessary in a built-up area.

Mechanical Loader

A new type of tractor-shovel is described. It is marketed by the International Harvester Company and is designed for use with their T.D.6 tractor. The bucket has a truck capacity of $\frac{3}{4}$ yd. Discharge of the bucket is effected by a separate automatic tripping action.

Notes from *Civil Engineering*, November 1954

Drilling Through Reinforced Concrete

On a site in the north-west of England, it was necessary to find some method of drilling, twenty-eight holes, 5 in. diameter, through concrete walls 4 ft. 6 in. thick. The article describes the method by which this was achieved, and gives a description of what may be termed really tough going, as the concrete was reinforced by $1\frac{1}{8}$ in. diameter mild steel at 9-in. centres, both vertically and horizontally, in each face.

The inner face (which was not accessible) had an aluminium cladding fixed to the wall with Rawlbolts, and for certain reasons it was decided that it would be wrong to assume that the steel had been fixed accurately; it was, therefore, necessary to find a drill capable of cutting through mild steel embedded in concrete. Such a drill was found in the form of a C.P. No. 5 diamond drill, manufactured by the Consolidated Pneumatic Tool Co. Ltd., and the necessary holes were drilled accurately and reasonably rapidly.

This is a core type drill and certain precautions were necessary when steel was encountered; a special core lifting device was used throughout the operation. The attention of engineers is drawn to this remarkable machine.

Bricks from Fly Ash

Fly ash has been in the news recently due to experiments which have been carried out in the U.S.A. on the manufacture of a cheap substitute for ordinary Portland cement. Strangely enough, the extreme fineness and chemical properties of fly ash are not unlike those of O.P.C., and this fact has been readily recognized and examined by the Americans.

As a result of successful research in this country by the Building Research Station, the British Electricity Authority is also considering brickworks at power stations. The article points out that British power stations produce more than 2 million tons of fly ash per year, and its disposal presents a big problem to power station engineers.

Bricks consisting of 85 per cent fly ash and 15 per cent clay are now visualized.

Tower Cranes on Building Sites

Tall tower cranes on building work are a familiar sight these days, and they have been brought into general use, rather in the same way as the scotch derrick is now used almost universally on large civil engineering sites. A certain amount of user experience with tower cranes is now available, and an interesting article on the subject has been written, from which the following conclusions are drawn:—

They occupy little space and can be sited close up to a building without reducing the area of effective operation.

They can handle any type of component or constructional unit, including large sections prefabricated on the ground, and, if suitable containers are used, any kind of building material.

They can pick up from lorries or from central dumps and deliver direct to the point where the work is actually proceeding. Their versatility enables them to take the place of several items of plant normally in use at one time, e.g., small hoists, derrick cranes and powered barrows. They reduce the number of handling teams and for many operations require no supporting banksmen. Although their capital cost is considerable, maintenance and running costs are low. Hire charges vary. Savings can be effected in specific operations in the amount of other plant and equipment needed and any overheads which depend on the time taken to complete the job. Economic use depends on keeping the crane fully employed. This involves careful dovetailing and timing of operations. Delays are more serious than in ordinary conditions, but it is to everyone's interest, including that of the operatives, to prevent them.

Embankments Stabilized by Grouting

In August, 1953, an article appeared in *Civil Engineering and Public Works Review* entitled "Grouting a Railway Embankment", in which a method was described for the stabilization of an embankment by deep grouting. In view of the satisfactory performance of the method adopted, it was decided to excavate three inspection trenches at sites which had been grouted in order to observe the pattern of distribution of grout through the soil mass. The sites chosen were as follows:—

1. The slip 95¼ miles approximately from Paddington, down side. This is an old slip that had been injected with neat cement grout mixed by the Colcrete process.
2. The slip at 95½ miles approximately up side. This is a more recent slip injected with aerated neat cement grout mixed by the Aerocem process.
3. A site a little beyond 95½ miles, down side, where an incipient slip had been prevented by injection of Aerocem neat grout.

This month's article describes in a most interesting way how excavations have been made to these embankments and the actual path of the cement grout stabilizing mix ascertained.

Soil Stabilized Runway

There is a most interesting article on a large soil cement stabilization project which has recently been completed at Somerford Airfield, Christchurch, Hants. The project involved the replacement of a permanent grass runway by a soil stabilized runway, 4,500 ft. long and 100 ft. wide and suitable for the heavier types of jet aircraft. The work of stabilization was carried out very largely by Howard single-pass soil stabilization plant, made by Rotary Hoes Ltd., of Horndon, Essex. Three complete trains of this plant were on the site at Somerford, and it was the usual practice to have them working in echelon.

Preliminary trials included stringent tests with service aircraft, with several different types of surfacing. As a result, three types have been selected for long term test. Part of the runway will be surfaced with tar and chippings, part with a 2-in. tarmac carpet and part with Jetcrete, which is a special emulsion developed for runways used by jet aircraft. During the project the opportunity has been taken to carry out troop trials with the plant.

The work formed part of the Ministry of Supply's experimental programme and was carried out by the Military Engineering Experimental Establishment, Christchurch, with the co-operation of the Royal Engineers.

Review of Contractors Plant

Rock Drill Steels

Readers who are familiar either with American rock tunnelling or quarrying will also be familiar with tungsten-carbide tipped rock drill steels manufactured by the Atlas Steel Company of Sweden. Another Swedish firm, the Hellefors Works of Sweden, has just introduced into this country their Vulcanus drill steel which has a sintered-carbide chisel bit and is made from ⅞, ¾ and 1 in. steel. The bit has an almost round crown with channels to facilitate flushing, and flushing holes positioned well forward. The drill steels are available either collared or with straight shanks and in a wide range of standard sizes, but other sizes and types can be supplied to meet special requirements. Some fractures in drill steels are often caused by weaknesses which develop in the hollow interior of the stem, mainly as the result of corrosion, and Hellefors have introduced a special stainless steel lining as a safeguard against corrosion. By concentrating on two important factors which govern performance, the makers claim to have succeeded in considerably increasing the average life of the drill steels.

New Heavy Duty Dumper

Amongst the range of plant being shown at the Public Works and Municipal Services Congress and Exhibition is the Aveling-Barford 7½-yd. heavy duty diesel dumper. The new dumper has undergone a period of twelve months of rigorous testing in the hands of many users. It carries a payload of up to 20,000 lb. and is claimed to have a performance superior to comparable dumpers, due partly to a higher ratio of engine power to gross laden weight. The engine, a Leyland six-cylinder diesel, develops 150 b.h.p. at 2,200 r.p.m., whilst the laden weight is 40,320 lb. Fully loaded the dumper can negotiate a 1 in 4 gradient.

3½ yd. Lima Excavator

The Lima 1201 dragline excavator is now being built in Britain by the North British Locomotive Co. Ltd., Glasgow, and is distributed by Jack Olding & Co. Ltd., Hatfield.

The 1201 may be supplied with dragline, face shovel or crane front end equipment. The standard dragline beam is 80 ft. long, but this may be reduced to 60 ft. by the removal of the centre section or extended by the use of 10-ft. inserts. The excavator is powered by a Crossley four-cylinder, two-cycle, single-acting diesel engine, which develops 240 b.h.p. at its governed speed of 875 r.p.m.

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada* (three papers from the issues for September and October, 1954).

The Automatic Factory

The automatic factory has not yet arrived, but it is on its way. Hitherto manufacture has, in the main, relied upon batch processes in which artisans were trained to control various operations and to check the quality of the product by sampling constituents at different stages. The more complex the process, the more equipment and the more operators required. Rising labour costs and the need for increased production have outmoded this method. The continuous system which is replacing it calls for constant measurement of process-variables at each stage, and for the immediate correction of any tendency to swerve from the ideal. The human operator is therefore being ousted by instruments installed at each process stage to measure, record and even adjust variables such as quantity flow, temperature, pressure and mechanical performance. The instrument engineer, who supplies the brain behind the eyes, ears and hands provided by his instruments, is likely to become one of the most important people in modern industry.

Instrumenting a nylon intermediates plant (October, 1954)

This paper outlines the instrument-control of a complex plant producing the raw materials required for spinning nylon staple and yarn. The process is chemical rather than mechanical, and the system of transmitting readings from instruments recording physical conditions to the centralized control panels is basically simple. In general, transmission is pneumatic, the instruments passing air pressure signals which actuate pressure gauges on the control panel through a "nerve system" of ¼-in. copper tubing. On the control panels the information is displayed in graphic form, and automatic alarms are incorporated to draw attention to critical conditions.

Electronics in the pulp and paper industry (September, 1954)

This article gives a brief but very clear and interesting description of the paper-making process and provides an excellent example of the application of electronics to a wide variety of controls in a complicated manufacturing process. From the detection of small pieces of metal within a log passing to the stripping and grinding machinery, up to the final inspection of the finished paper for accuracy of gauge and absence of faults and pinholes, electronic controls and monitors can be used at every stage. Various combinations of electronics properties—rectifying, amplifying, voltage regulation, light sensitivity—are used for the immediate adjustment of speed drives, for regulating grinder loads, for monitoring moisture content, draw speed, tension and weight gauge. If a paper break occurs, the photoelectric tube output can either sound an alarm or shut down the first pulp press and thereby break down the paper sheet. Besides providing automatic operation, the degree of accuracy achieved in control and inspection is far in advance of that obtainable by earlier techniques.

The application of computors to industry (September, 1954)

The so-called electronic brain is already quite commonly used for a a variety of commercial purposes, including the control of airport traffic, taking inventories and producing stock reports, calculating load distribution on power-supply networks and predicting anything from election results to sales demands as soon as enough data is available to indicate trends. The computor can already assume complete charge of an automatic milling machine and, in the not very distant future, it is likely that it will be developed to undertake supervision and virtually complete control of a fully-automatic factory.

Notes from *The Engineering Journal of Canada*, September, 1954.

ENGINEERING ASPECTS OF THE PERIBONKA DEVELOPMENTS

Of recent years the development of hydro-electric power has progressed at amazing speed in Canada, and several papers from *The Engineering Journal* have already been noted in the *R.E. Journal.*

The Peribonka developments are particularly interesting because of the speed of erection and installation, both plants being in operation within twenty-one months of the start of construction. This paper is remarkable as covering all main aspects of the project and as dealing with two separate installations simultaneously.

Oblique aerial photographs give an excellent idea of the size and general layout of the two plants, and various features are also well illustrated: the cover picture of *The Engineering Journal* shows the unusual semi-open design which replaces conventional power house superstructure.

The problem of de-watering and the difficulties encountered in obtaining sound foundations are described, and the measures adopted to seal cracks and openings in the bed rock are interesting. Design and construction of bulkhead dams, regulating gates, sluices and spillways, log chutes, intakes and power houses are discussed, and concise details are given of turbines, generators, auxiliaries and distribution, including the system of control, metering, fire-protection, heating, lighting and communications.

Notes from *The Engineering Journal of Canada*, October, 1954.

C.N.R's. EXTENSION FROM SHERRIDON TO LYNN LAKE

The railway extension serves a nickel and copper mine at Lynn Lake, 120 miles north of the previous railhead at Sherridon, and some valuable lessons are to be learned from this short but comprehensive account of its location and construction through virgin country, in sub-Arctic climatic conditions.

Since the only practical method of transport in summer was by air, all heavy materials, equipment and supplies had to be hauled over a winter tractor trail.

As in the case of the Quebec Northshore and Labrador Railway (Technical Notes, *R.E. Journal*, December, 1954), aerial survey was found to be impracticable owing to inadequate ground control, and normal preliminary ground survey was carried out after air reconnaissance and the study of air photographs. The maximum gradient was laid down as 1.75 per cent (approximately 1 in 60) and maximum curvature as 15 deg. (radius approximately 383 feet), the final length of the alignment selected being 144 miles, a notably small amount of development considering the obstacles to be overcome. Muskeg, rock and permafrost areas were avoided as far as possible in order to save both time and expense.

It is perhaps surprising to learn that clearing work was carried out by hand, after abandoning the use of power equipment for this purpose. The reason given is that, when using machines, it was found too difficult to pile debris so that it could be burnt.

The principal obstacle was the Churchill River. Three channels were crossed by prefabricated steel truss spans, the members being hauled over the winter tractor trail and the bridges erected during the summer, before the track was laid. Fifty-five timber bridges were also erected ahead of grading, this being done in winter when material and plant could be moved over frozen ground and swamps from site to site.

Drilling and grading work were done by normal types of plant; track-laying by a special self-propelled machine; and ballasting by specially equipped dozers, power jacks and power tamping machines. The only operation carried out entirely by men was lining the track to the centre stakes.

Reconnaissance started in February, 1951; grading on 29th September, 1951; the track reached the mine plant on 23rd October, 1953, and the first carload of freight was delivered three days later, a week ahead of schedule. Three or four round trips are now operated weekly by diesel-electric locomotives hauling up to 1,600 tons gross on the maximum gradients.

Notes from *The Engineering Journal of Canada*, November, 1954.

NECHAKO—KEMANO—KITIMAT DEVELOPMENT

The entire technical section of the November issue, extending to ninety-nine pages, is devoted to a series of papers dealing with this gigantic project, some aspects of which have been the subject of previous notes (*R.E. Journal*, March and September, 1953). Subjects covered include the hydrological survey, dam construction, driving the 10-mile tunnels which carry the intake to the underground power station, design and construction of the 51-mile transmission line and towers, the planning and erection of the aluminium smelting plant and construction of the harbour at Kitimat. These papers are well worth reading, for they describe a classic engineering feat. All emphasize parts of the project involving unusual problems, and they contain much valuable data and many most interesting ideas.