THE ROYAL ENGINEERS JOURNAL—DECEMBER 1958

THE ROYAL ENGINEERS JOURNAL

Vol. LXXII DECEMBER 1958 No. 4

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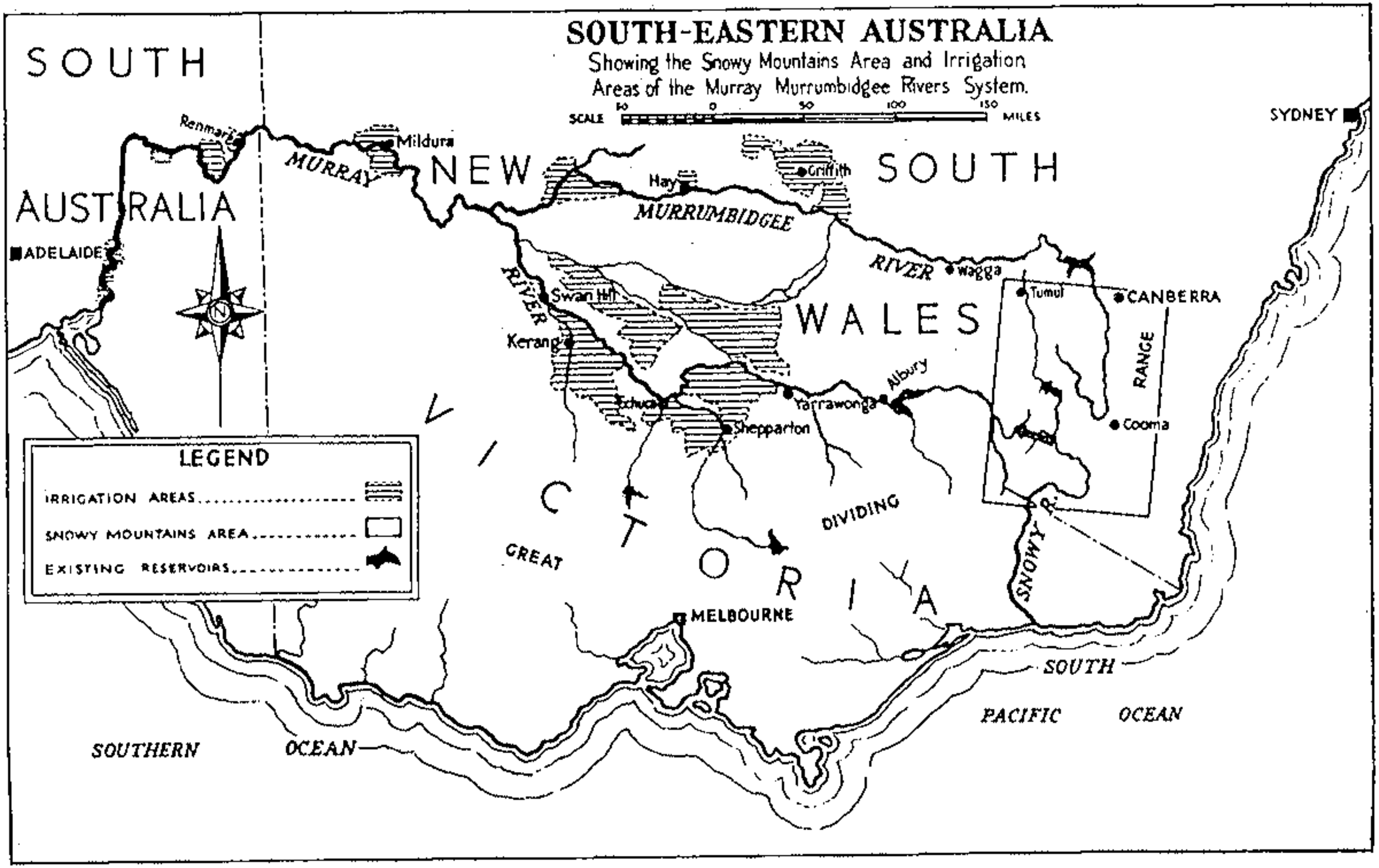


South-Eastern Australia.

The Snowy Mountains Scheme

By Colonel M. W. Biggs, O.B.E.

Introduction

The Snowy Mountains Scheme is a combined hydro-electric and irrigation development in eastern Australia. It is one of the largest and most complex engineering works ever undertaken in the world, comparable in magnitude to the great Tennessee Valley Authority's development in the U.S.A. It is controlled by the Snowy Mountains Hydro-Electric Authority headed by a Commissioner appointed by the Governor-General, and responsible to the Commonwealth Minister for National Development.

In 1956 the present Engineer-in-Chief visited Australia to observe the "Buffalo" series of atomic trials at Maralinga. He took the opportunity of visiting the Snowy Scheme, when he found that the Royal Australian Engineers had one (now two) regular officers attached to the authority. The Commissioner (Sir William Hudson) welcomed his suggestion that Royal Engineer officers should be similarly attached to gain experience in the wide variety of work being carried out by the authority. Subsequently the Engineer-in-Chief was able to persuade the War Office to grant the necessary financial and other authority for these attachments. The first two Royal Engineer officers were sent out to Australia in the middle of this year, for a tour of two years, most of which will be working with the Snowy Mountains Authority, and the balance for visiting R.A.E. and other installations and for leave.

I hope that this description of the scheme will appeal not only to those fortunate officers who may be selected for this attachment in future years, but to other Sapper officers who are interested in a vast scheme of Commonwealth development and its formidable engineering aspects.

I would like to express my gratitude to Sir William Hudson for providing me with so much material about the scheme, for permission to quote from it and to reproduce the photographs; as well as for V.I.P. treatment for visits to the different parts of the scheme in 1957.

Scope of the Scheme

Australia is the driest continent in the world. Four-fifths of the interior is useless desert with negligible rainfall. Nevertheless there are large areas where climate and soil conditions are ideal for fruitful production, given the requisite water by artificial irrigation or other means. It has been repeatedly stated that the limiting factor in Australia's future development and the size of population she can eventually sustain will be water.

Conversely Australia is short of power. It is said that probably no single factor has a greater influence on the prosperity of a country than the use made of power; also that industrial output almost exactly follows power usage. Canada is an outstanding example of remarkable industrial development and high standards of living stemming directly from the use she is making of her abundant power resources. Australia's usage of power per capita lags far behind that of Canada, the United States, Great Britain and other West European countries. With a vigorous immigration programme aimed at raising the population between 2 and 3 per cent per annum, and increasing industrialization with the establishment of more secondary industries, Australia's demands for more power are increasing yearly.

To cope with these demands for more water and more power the Snowy Mountains Scheme plans to turn the waters of the Snowy River westward through tunnels under the Great Dividing Range to irrigate the dry plains of the inland, instead of letting them flow uselessly southward into the sea. In so doing the vast power potential of the falling water is to be harnessed in a series of power stations, most of them hundreds of feet underground. Ultimately the scheme will make available annually nearly 2 million acre-feet of water for irrigation and will provide approximately 3 million kW. of power.

Background

Geography (Frontispiece). The Great Dividing Range runs more or less parallel to the South Pacific Ocean all the way up Australia's eastern seaboard from the south coast of Victoria to the north of Queensland, and divides the comparatively narrow well-watered coastal plain from the great arid spaces of the interior. It rises to its highest elevation on the borders of New South Wales and Victoria, to form the Australian Alps, which include the Snowy Mountains. The latter extend in a belt of ranges fifteen to twenty miles wide and some hundred miles from north to south, a large proportion of it at altitudes greater than 5,000 feet and rising to a maximum of 7,313 ft. at Mount Kosciusko, the highest mountain in Australia. The height of these mountains and their proximity to the ocean enable the global windstream of the "roaring forties" to produce upon them precipitation five to ten times that received at other places in Australia at the same latitude. The peaks and higher ranges are snow-clad for six months of the year; the depth of snow varies from year to year, but the snowfall never fails. This, combined with heavy summer rainfall, makes the Snowy Mountains Australia's most reliable catchment, and the area is, by Australian standards, a land of ever-flowing streams.

The area is the source of the westward flowing Murray and Murrumbidgee Rivers, which cross dry but otherwise fertile plains stretching for hundreds of miles to the coast of South Australia, and of their tributaries the Tumut and the Swampy Plains Rivers. On the inland or western side the ranges are bounded by fault escarpments sloping steeply down from the snow-line to the deep valleys of these rivers, but on the coastal, or eastern side of the Mountains the country is virtually a plateau sloping away much more gradually. Consequently the greatest percentage of the run-off from rain and melted snow is collected by the Snowy River and its tributary the Eucumbene, which derive their water from this plateau and flow eastward and southward to the sea through country already well-watered by adequate rainfall. As a result millions of gallons of water are lost annually to the Tasman Sea, which might be used profitably along the valleys of the Murray and Murrumbidgee where irrigation farming is already an established and prosperous industry, limited only by the extent of the summer flow of these rivers.

History. It is not surprising therefore that, in a country noted for the paucity of its water resources, the potential of the Snowy River has attracted attention for over seventy years. In that period surveys were made and many different proposals produced for utilizing the water—to augment Sydney's water supply, and to produce power for the south coast and Gippsland area of Victoria, as well as for irrigation in the Murrumbidgee Valley. None of these regional schemes would have utilized the full potential of the Snowy River, and it was not until after the 1939–45 war that its maximum development for both irrigation and power was appreciated by the Commonwealth Government, together with the Governments of New South Wales and Victoria, as being a matter of national importance. After a Premiers' Conference in 1947 a Technical Committee set to work to examine all proposals. It produced two reports, one in November 1948, recommending the immediate adoption of a scheme to direct substantial quantities of water from the Snowy catchment to the Tumut, a tributary of the Murrumbidgee, and a second in June 1949, recommending that the balance of the Snowy waters be directed to the Murray. Both these recommendations were approved by the three governments, and action was taken immediately to implement them. The Snowy Mountains Hydro-Electric Power Act of July 1949, established the Snowy Mountains Authority and authorized it to generate electricity by means of hydro-electric works in the Snowy Mountains Area, to supply electricity for defence purposes and for consumption in the Australian Capital Territory, and to sell electricity to the States; it also gave the authority powers to construct and operate works in the area for the collection, diversion and storage of water, for the generation and transmission of electricity and for purposes incidental to these activities. Construction operations began immediately the Act was passed.

A detailed supporting agreement between the Commonwealth and the States of New South Wales and Victoria regarding the construction and operation of the scheme and the distribution of power and water was only signed late in 1957. This agreement also legalizes the Snowy Mountains Advisory Council, in which the electricity and irrigation authorities of the two states meet with those of the Commonwealth and representatives of the Authority to sort out matters of mutual concern and to direct the operations of completed parts of the scheme.

The costs of construction are being met initially from Commonwealth funds, repayment to be effected by the sale of electric power. Although future generations may well judge the diversion of the water to make major extension of the inland irrigation areas as being the scheme's most valuable contribution to the development of the nation, this water is to be supplied free to the riverine states, and the whole cost of the scheme has to be met from the charges for the supply of power.

Description

General (see Fig. 1). The scheme involves a large amount of tunnelling, the location of many of the power stations underground and the use of very high voltage transmission lines to convey the energy produced to the load centres in New South Wales and Victoria. The 330,000 volt transmission system will be the first of its kind in the southern hemisphere, and will form an important link between the power distribution systems of the two states.

An essential feature of the scheme is the provision of a number of large regulating water storages. For both power production and irrigation the run-off must be regulated to a considerable degree. Although the annual snow-cover on the higher ground affords some retention and regulation of run-off, the flow of the river in the area is seasonal and varies considerably from year to year. The scheme therefore provides for three large storage reservoirs, the largest on the Eucumbene at Adaminaby, a second on the Snowy at Jindabyne, and a third at Tantangara on the Upper Murrumbidgee, besides several smaller ones.

The complete scheme will involve the construction of nine major dams of structural height greater than 200 ft., a dozen lesser ones, fifteen power stations, most of them hundreds of feet underground, over eighty miles of major tunnels half with diameters greater than twenty feet, and 400 miles of aqueducts and racelines to pick up waters at high altitudes and head them into storages and tunnels.

The scheme as finally approved is divided geographically into two sections:—

A. *The Snowy-Murray Development*, which provides for the diversion of the main stream of the Snowy River at Jindabyne to the Upper Murray River.

B. *The Snowy-Tumut Development*, which provides for the diversion of the Snowy's tributary, the Eucumbene, at Adaminaby to the Upper Tumut River.

The Snowy-Murray Development (see Fig. 2)

The Snowy River rises near the summit of Mount Kosciusko and flows down the eastern slopes of the mountains to the Jindabyne Valley. The principal feature of this development is the damming of the river about a mile downstream from the Jindabyne township, and the diversion of the main stream through tunnels under the Great Dividing Range into the Swampy Plains River in the valley of the Upper Murray.

The Jindabyne Dam will be an earth and rock fill embankment 275 ft. high, impounding a net storage of 1,100,000 area-feet of water, three times the volume of Sydney Harbour. The present town of Jindabyne will be submerged, and a new town is to be built on higher ground overlooking the dam.

The Snowy-Murray Tunnel will be nearly thirty miles in length and about eighty feet in diameter. It will be some 3,800 feet below surface level where it passes beneath the crest of the range. The tunnel will pass below a balancing pondage on the Geehi River, another tributary of the Murray, 19 miles from the Jindabyne portal. Between Geehi Pond and the point of discharge into the Swampy Plain River, the diverted waters will fall some 2,000 feet in two stages, developing 1 million kW. of power in two large underground power stations, M6 and M7. At Island Bend half way along the length of the Jindabyne-Geehi section of the tunnel, it crosses below the Snowy River; at this point a shaft about 1,000 feet in depth, which will initially serve as a point of access for construction of the tunnel, will later be used to bring down water from the Upper Snowy into the tunnel, generating power in another power station, M3, to be built into the base of the shaft.

Supplementary to the main Snowy-Murray Diversion are two series of power developments of the Upper Snowy and Upper Geehi Rivers. The Upper Snowy group comprises four power stations in addition to M3, referred to above, which will use the 1,800-ft. fall of the river between Kosciusko Reservoir at 5,770 ft. and Island Bend 3,930 ft. elevation. The total capacity of these four stations will be about 485,000 kW. The first of them (M.I.B), the *Guthega Project* came into operation producing 60,000 kW. in February 1955.

Similar developments of the Upper Geehi on the western side of the divide will utilize the upper reaches of that river from an altitude of 5,190 ft. through a series of three power stations down to the level of the Geehi Pondage.

The same water will thus be used over and over again. For example water caught on the eastern slope of Mount Kosciusko will pass through six power stations in its fall of 4,500 ft. to the Murray Valley.

THE SNOWY-TUMUT DEVELOPMENT (see Fig. 3)

This section of the scheme is even more complex. The works involve the diversion and regulation of the Eucumbene, Upper Tooma, Upper Murrumbidgee and Upper Tumut Rivers. Their combined flow will then be passed through a series of power stations along 30 miles of the Tumut Gorge.

The Eucumbene, the Snowy's largest tributary, will be checked and stored by a dam at Eaglehawk, near Adaminaby. This dam will also receive water from the Upper Murrumbidgee, which is to be dammed at Tantangara and diverted through 10 miles of tunnel. From the Adaminaby Dam the combined waters of these two rivers will be diverted westward through a 14-mile tunnel under the Great Dividing Range to Tumut Pond on the Tumut River. In Tumut Pond, a balancing and regulating storage to control the diverted waters, they will be joined also by water diverted from the Upper Tooma, a tributary of the Murray. All these waters will be released to flow successively through a series of five power stations down the gorge of the Tumut River, developing a total of 1,070,000 kW. as they fall 2,000 ft.

Adaminaby Dam will be one of the highest (300 ft.) earth and rock fill dams in the world. Its construction will involve the placing of 9,500,000 cu. yds. of fill. It will store a net volume of 3,500,000 acre-feet of water, more than eight times the volume of Sydney Harbour. It also will inundate the town from which it takes its name, and a new Adaminaby has been built on higher ground 5 miles to the north-east.

The Eucumbene-Tumut Tunnel will be approximately fourteen miles in length and twenty-one feet in diameter. It is designed so that, in addition to its normal task of carrying the stored waters westward from the Adaminaby Dam to the Tumut Pond balancing reservoir, in times of flood water from the Tumut and Tooma Rivers can be diverted *eastward* through it into

Adaminaby Dam to be held in storage for future use. As a further refinement, and since it has not been found practicable to carry Tumut Pond Dam up to a height sufficient to cause this reversal of flow in all circumstances, provision has been made for closing the western end of the tunnel by means of a valve, and diverting the Tooma and Tumut waters into the tunnel by a 300-ft. shaft at the confluence of the Upper Tumut and Happy Jacks Rivers. This shaft serves currently also as a shaft of access for the construction of the tunnel.

Tumut Pond Dam will be a concrete arch structure 290 ft. in height and 650 ft. in crest length, providing a gross storage of 43,000 acre-feet. The dam site is a V-shaped gorge with relatively sound granite outcroppings on both abutments. Provision will be made for a spillway, controlled by two radial gates, and river outlets.

Water from Tumut Pond Dam will flow through a pressure tunnel 8,000 ft. long by 21 ft. in diameter to a surge chamber immediately above the first power station (T1).

T1 Power Station is typical of a number of underground stations which will be built for the scheme, and is therefore worth describing in some detail. It will be located in an underground chamber in granite, 1,000 ft. below ground level. Twin vertical pressure shafts 12 ft. in diameter will drop the water down from the surge chamber a vertical distance of 800 ft. to four turbo-generators, with a total capacity of 320,000 kW. and operating under an average net head of 1,050 ft. From the turbines the water goes by a 4,000 ft. tailrace tunnel leading back into the Tumut River further downstream.

The machine hall will be a chamber 305 ft. long by 59 ft. wide, with a maximum height of 105 ft., with transformers in an adjoining chamber. Access will be through a 1,400 ft. vehicular tunnel excavated on a downgrade of 1 in 8 from the river bank or by a 1,200 ft. personnel lift.

Power will be delivered from the generators at 12,500 volts to a bank of underground transformers, which will raise the voltage to 330,000 volts. Power will be led at this voltage through high tension cables to the surface, and thence away by high voltage overhead lines to a central switching station, and on to the load centres in New South Wales and Victoria.

T2 Power Station. Water returned to the Tumut from Station T1 will be caught by a dam 1½ miles further downstream, thence taken through a 15,700 ft. tunnel to a surge chamber above another power station (T2). This one will be similar to T1, but 650 ft. below the surface and with a total capacity of 280,000 kW. A tunnel 4 miles long will carry the water from T2 back into the Tumut River.

Downstream of T2 further developments will take the form of three more reservoirs, known as Lob's Hole, Cumberland and Blowering Reservoirs, each with an associated power station (T5, T6, and T7) downstream of the dam. The total installed capacity of these three stations will be 470,000 kW.

The last of these four pondages, Blowering Reservoir, will be built by the Water Conservation and Irrigation Commission of New South Wales to store water discharged from the Upper Tumut projects during the winter and to release it during the summer when required for irrigation in the Murrumbidgee Valley.

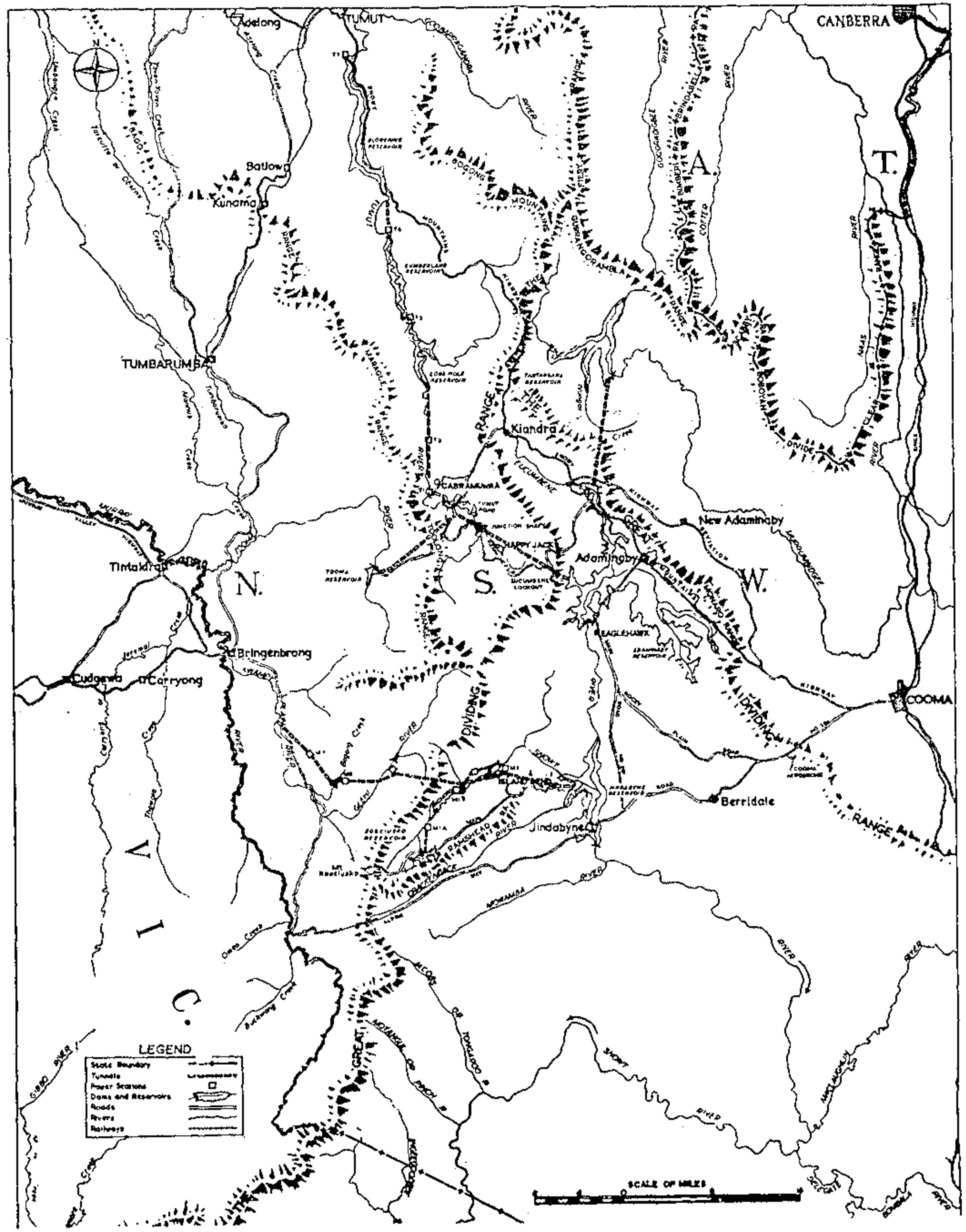


Fig. 1.—The Snowy Mountains Scheme.

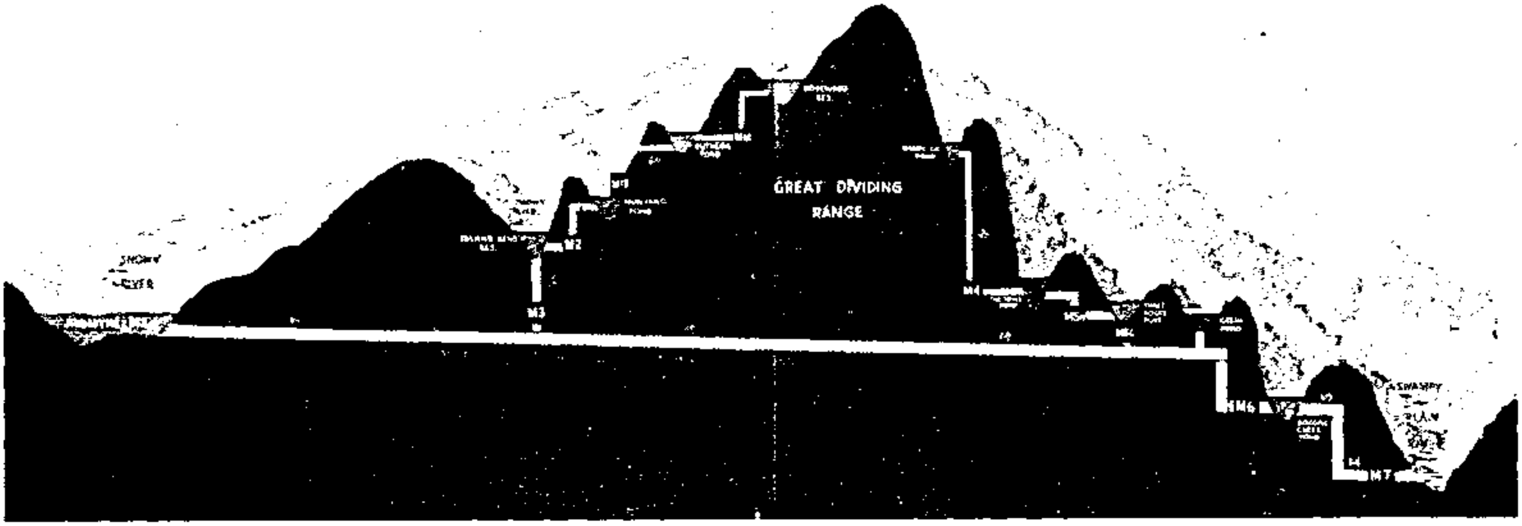


Fig. 2.—The Snowy-Murray Development.

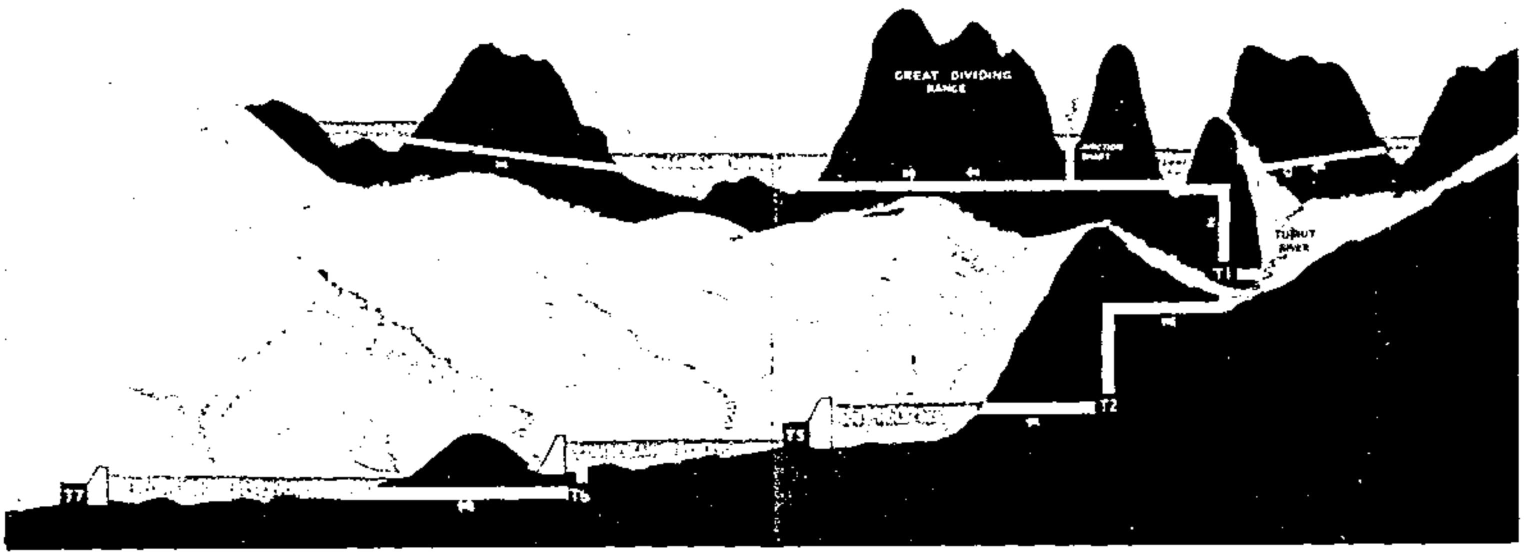


Fig. 3.—The Snowy-Tumut Development.

The Tooma-Tumut Diversion is a subsidiary works whose function is to provide additional water from the Upper Tooma River to the series of power stations in the Tumut River. An earth and rock fill dam 220 ft. high will check the Upper Tooma near its confluence with Toolong Creek, forming a reservoir with net storage capacity of 22,000 acre-feet. From this reservoir a tunnel about nine miles long will lead these waters to Tumut Pond, collecting additional waters from tributary streams through shafts into the tunnel.

The Murrumbidgee-Eucumbene Diversion will divert the Upper Murrumbidgee southwards into the Adaminaby Reservoir, further augmenting the flow of water through the Tumut River power stations. The Tantangara Dam on the Upper Murrumbidgee will be 200 ft. high and will contain 500,000 acre-feet of water, which will be carried by a $9\frac{1}{2}$-mile long tunnel through the main divide, at a maximum depth below the surface of 1,500 ft.

Planning and Progress

Preliminaries. The work of the Snowy River Committee up to 1949 was limited by lack of accurate data. Access to the area was difficult, records were limited and much of the planning had to be based on aerial photographs and approximate mapping.

When the authority was formed on 1st August, 1949, its immediate task was to obtain and study basic data to confirm the broad estimates and plans of the Committee and to extend its work in much greater detail. An intensive programme of collection, assembly and analysis of a mass of field data was embarked upon. A large area of virgin mountainous country with negligible population and non-existent communications had to be surveyed and maps prepared, and hydrological and geological information had to be gathered, much of it in places inaccessible except on foot or pack horse. Upon the results of this work general investigation of the whole scheme had to be followed by studies to determine the basis for the development of each project, and investigations of the sites of proposed structures.

Access tracks had to be made to open up the area and facilitate field investigations. These were followed by a system of permanent roads to the main works areas. Besides the headquarters of the authority at Cooma, some seventy road miles south of Canberra, two regional centres, at Island Bend in the southern section and at Cabramurra in the northern section, were established as bases from which further investigations and construction were carried out. A system of radio and telephone communications and a power network were established throughout the area. Much of the early road and camp construction was carried out during the winter months when snow and low temperatures made work very difficult. In all 100 miles of public roads have been reconstructed, 110 miles of new heavy duty roads and 150 miles of light roads and access tracks have been built. Three more townships and a number of large construction camps have been built, including 800 houses, messes, hostels, office buildings, shops, stores, recreation facilities, water and electricity supplies, workshops and probably the largest civil engineering laboratories in Australia.

Meanwhile a large and entirely new organization had to be built up from scratch. The acute shortage of professional men and tradesmen in Australia at that time necessitated intensive recruitment in Great Britain, Western

Europe and New Zealand of these essential staff. Organizational practices and procedures had to be established, and taught to many of the new staff who had only scanty knowledge of English.

The staff now numbers over 1,000 officers, including some 340 engineers, geologists, physicists, soil conservationists and other professional men.

Faced with the problem of building up this large organization and commencing major construction work at the earliest possible date, the authority sought and obtained the help of the Bureau of Reclamation of the United States' Department of the Interior in the preparation of designs and specifications. The bureau, with fifty years' experience of this type of work, was able to give invaluable technical assistance and advice on staff training. It prepared the designs and specifications for about two-thirds of the authority's contracts, and trained numbers of the authority's staff on large construction works in the United States. The bureau also made available the services of a group of experienced engineering advisers who took up residence in the area.

Apart from the preliminary pioneering work it has been the authority's policy to arrange for the construction of permanent works to be carried out by contract. With the objectives of the generation of some power and the diversion of some irrigation water at the earliest possible date, for reasons of political and public opinion as well as for practical ones, design followed closely upon the results of the investigational studies, and the first contract was let towards the end of 1951.

The Guthega Project was selected because it is a simple hydro-electric scheme which offered the best possibilities of developing power in a comparatively short space of time, and required less preparatory work than other larger projects. It comprises a 110 ft. high concrete dam, a 3-mile tunnel and a 60,000-kW. power station.

The contract for the civil engineering work was won by a Norwegian firm, Selmer Engineering, whilst the electrical contract for the supply of the generators was secured by the English Electric Company. It is worth observing rather sadly at this point that the latter, and that for the turbines at T1 power station, are the only significant contracts in this huge engineering scheme which have been so far won by a British firm. Other large parts of it are being carried out by American and French firms, but the United Kingdom does not feature elsewhere. This is adversely commented upon by one's Australian friends, who see in it a basic lack of interest and support by us for the development of their country. Counter allegations that the contract specifications were loaded in favour of United States firms are not borne out by the fact that Norwegians and French have also won major contracts. The real reasons are doubtless purely commercial and financial, but the result is nevertheless unfortunate and does nothing to strengthen Commonwealth bonds.

Owing to the acute shortage of manpower and materials in Australia at the time, the successful tenderer was required to import 90 per cent of his labour and all materials in short supply. Consequently some 400 Norwegians came to Australia to work on this project. Subsequently, immigrants and imported labour from many other European countries followed to make, with the professional and supervisory staffs also recruited from overseas and the many native Australians who were recruited as the labour market improved, a working community of remarkable diversity.

The Guthega works area is at an elevation of some 5,200 ft., only a few miles from the summit of Mount Kosciusko, and is normally under snow from May to October. This part of the Australian Alps is one of the most popular winter sports centres; notices have been erected around the edges of the pond to warn skiers off its smooth snow-covered surface lest they fall through the ice crust when draw-down has lowered the water level beneath it. Low temperatures and snow conditions therefore made work during the winter difficult and hazardous, but construction proceeded winter and summer until its completion in February 1955. The first fruits of their great scheme were then visible to the Australian public as power flowed from the Guthega generators into the New South Wales transmission network. It is also of use to the authority for construction purposes in the area of the scheme.

The authority's own forces constructed the high voltage lines to carry the power from Guthega to Cooma, and hundreds of miles of lower voltage lines for distribution of construction power throughout the area, and they also constructed many miles of concrete aqueducts to divert the waters of numerous mountain streams into the main pondage.

Adaminaby Dam. The next major part of the scheme to be tackled was the construction of the Adaminaby Dam, which is being constructed for the authority by the New South Wales Public Works Department. Construction on a large scale began in 1953, and stripping of the abutments of the dam-foundation, consolidation grouting, and other preliminary works were completed by them in 1955. Simultaneously a 2,300 ft. long diversion tunnel of 25 ft. diameter around the dam site was completed by Allied Constructions as sub-contractors for the department. This permitted a start to be made on placing the earth and rock fill, for the major part of which a contract was placed with Kaiser-Walsh-Perini-Raymond, a group of American contractors.

The height of the dam had risen sufficiently by mid 1957 for the gates of the diversion tunnel to be closed, starting the storage of water behind the partially completed wall and the slow flooding of the wide smiling valley above it.

When visiting the area before then it was difficult to visualize how it would look after the completion of the dam in 1959, and the total flooding of the plain. A notice high up on the approach road from Cooma winding down into the valley, and a similar one miles further on when leaving the valley towards the mountains beyond, proclaimed the future water level. In the vast area between, fields, trees, farmhouses and villages were all to be inundated under a smooth sheet of water. The main Monaro Highway, now renamed the Snowy Mountains Highway, had been diverted around the eastern side of the reservoir over a length of 31 miles by the Department of Main Roads assisted by the authority's construction forces in winter. The township of Adaminaby was dying in its old location and rising anew on higher ground 5 miles away on the eastern edge of the future reservoir. Our progress along the roads in the valley and elsewhere was more than once held up by the movement of houses being shifted complete on transporters from the old to the new site; furniture in place and electric lights visible inside swinging with the movement (see Photo 1). Where houses could not be moved bodily the inhabitants have been more than compensated by having new modern ones built for them.

At Eaglehawk close to the site of the dam a works township with over 200 homes and barrack blocks for the employees, besides offices and workshops, had grown up. The buildings here, as in the other works townships throughout the area, are mostly of pre-fabricated construction, so that they can be lifted and moved easily elsewhere when they are no longer required on that site.

From a viewpoint high above the dam site itself the whole sequence of operations in its construction could be seen in panorama below (see Photo 2). At the sides men were cleaning off the shoulders with water and air blast; an endless procession of scrapers and dump trucks were following each other up the access road from quarries downstream, bringing rock and earth fill to dump in ordered layers across the width of the dam; and bulldozers, graders and sheepsfoot rollers were smoothing out and consolidating the fill as it was laid.

Eucumbene-Tumut Tunnel. In October, 1954, the same group of American contractors who had won this £19¼ million contract began to drive the Eucumbene-Tumut tunnel, a distance of 14 miles from the Adaminaby Reservoir through the Great Dividing Range to the Tumut Pond Dam on the Tumut River. In addition to tunnelling from the Eucumbene portal at its southern end, a 300-ft. vertical shaft was sunk at a point near the confluence of the Tumut and Happy Jacks River called Junction Shaft, from which tunnellers drove outward in both directions.

Progress of this work was remarkable. The existing world record rates for excavation of a tunnel of this size in hard rock were repeatedly beaten. The best figure of nearly 500 feet in a week of six working days is more than four times as fast a rate as had previously been accepted as satisfactory in Australia, and it is interesting to record, in the light of criticisms which are often thrown at Australian workers, that many of the men employed in this tunnelling are native Australians. The remarkable results achieved show that Australians and New Australians under energetic drive and good leadership such as they have received from the Americans, with proper job planning and first-class equipment, can more than hold their own with workers from any part of the world.

To one not conversant with tunnelling on this scale, of most interest was the machine which lifted trucks bodily over each other near the face (sometimes called a "cherry picker" in English practice), thereby avoiding having to shunt full and empty ones to and fro in the confined space available. (See Photo 3.)

The tunnellers from the Eucumbene Portal and from Junction Shaft met in mid 1957. Meanwhile an Australian firm, Allied Constructions, as subcontractors to Kaiser-Walsh-Perini-Raymond, completed in 1955 a 4,000 ft. long access and drainage adit leading to the downstream end of the main tunnel from a point downstream of Tumut Pond Dam. It is estimated that the Eucumbene-Tumut tunnel will be in use by the end of 1959.

Tumut Pond Dam. The same American group of contractors also won the contract for the construction of this dam and associated pressure tunnel to the T1 power station and surge tank, totalling over £5½ million in value.

First a coffer dam was built across the river and a tunnel to divert the river around the dam site driven through the right shoulder of the narrow V-shaped gorge which is the site of this dam (see Photo 4). A concrete mixing

Photo 1.—House moving at Adaminaby.

Photo 2.—Adaminaby Dam—construction plant at work.

The Snowy Mountains Scheme 1 , 2

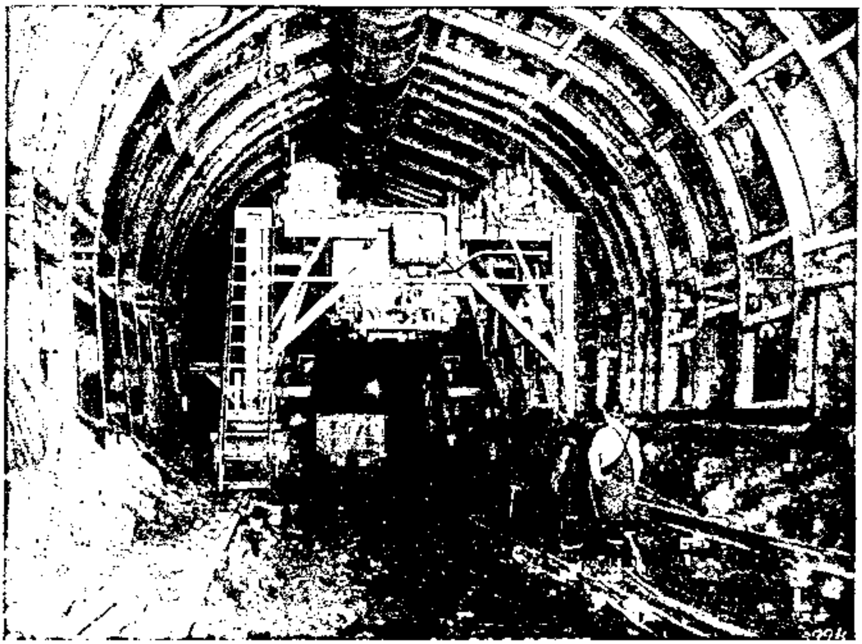


Photo 3. —Eucumbene-Tumut tunnel, "Cherry-picker" in operation.

plant was installed and when the excavation for the abutments and foundation were completed the placements of concrete began. The design of this great concrete structure embodies in it a through passage which can be used to check on seepage.

The dam was officially opened in September 1958.

T1 Power Station. The contract for the construction of T1 power station was won by a group of French contractors sponsored by Etudes et Enterprises with a tender of nearly £4 million, whilst the four turbines have been manufactured by English Electric and their generators by A.S.E.A. Electrics of Sweden. Each of these turbo-generators will generate 110,500 h.p. at 960 ft. net head and 375 revolutions per minute.

Access to the underground workings is from the bottom of a deep valley with precipitous sides near the works township of Cabramurra, down a vehicular tunnel of steep gradient. Up and down this tunnel were roaring giant Tournarocker dump trucks bringing out the excavated rock (see Photo 5) looking like prehistoric subterranean monsters belching out fumes and noise to drive intruders from their lair. At the face being worked the empty Tournarockers humped themselves up like cats to turn in the confined space, before backing up to be filled by the over-loading excavator which chucked back over its head the rock spoil from the heap which had been previously blasted. The fumes from all this underground activity are sucked out through ducts from the face along the sides of the access tunnel. Excavation of the machine hall and transformer hall, two huge man-made caves at right-angles to each other, the twin pressure shafts and the vertical shaft providing alternative access, have all now been completed. It is anticipated that the first two units will be in service by April 1959, when it is to be opened officially, and the whole project will be in full operation by the end of the year.

Photo 3.—Eucumbene-Tumut tunnel, "Cherry-picker" in operation.

Photo 4.—Tumut Pond dam site.

Future Programme

The immediate objective of the authority is the completion of the Upper Tumut Diversion Works and the T1 and T2 projects, to the following schedule of completion dates:—

Tumut Pond Dam	1958	(Opened September 1958)
T1 pressure tunnel	1958	
T1 power station (all four units)	1959	(two units April 1959)
Adaminaby dam	1959	(Completed June/July 1958)
Eucumbene–Tumut tunnel	1959	(Completed ? 1958)
Tooma–Tumut diversion	1959	
Murrumbidgee–Adaminaby diversion	1962	
T2 project (two units)	1962	
T2 project (four units)	1963	

(Latest information on completion dates obtained from Australia House on going to press is shown in brackets alongside this schedule.)

Power will then become available as follows:—

Guthega project, already in operation	60,000 kW.
T1 power station, April 1959	160,000 kW.; total 220,000 kW.
T1 power station, end 1959	320,000 kW.; total 380,000 kW.
T2 power station, in 1962	140,000 kW.; total 520,000 kW.
T2 power station, in 1963	280,000 kW.; total 660,000 kW.

Additional water for irrigation will be supplied to the Murrumbidgee as follows:—

1959	300,000 acre-ft. per annum
1961	200,000 acre-ft. per annum
Total	500,000 acre-ft. per annum

These water quantities will be almost doubled when Blowering Dam is completed by the State of New South Wales.

Detailed investigations and preparatory works by the authority which have been proceeding during the past three years should enable full-scale construction operations on the Snowy–Murray diversion to begin at both ends in 1959, on the Jindabyne Dam in 1961, on the 540,000 kW. M6 power station at Bogong Creek in 1960, and on the 540,000 kW. M7 power station at Swampy Plains shortly afterwards. If this schedule is adopted, the first water from the Snowy should reach the Murray in 1966. Future developments and rate of progress will depend upon the results of intensive office and field investigations of projects, the availability of funds, the rate of growth of power demand in New South Wales and Victoria and other factors. At Appendix A is a summary of the principal features of the whole scheme according to present plans, up to its completion, which may not be until 1983. The estimated total cost of the scheme will be £422 million.

Power Relationships

When completed the scheme will have added almost 3 million kW. of power and nearly 6,000 million kW.-hr. per annum of energy to New South Wales and Victoria to meet the needs of expanding industry and rapidly increasing population. (See Appendix A.) Of this available power Victoria will get 920,000 kW., while the rest, after satisfying Federal requirements in the Australian Capital Territory, will go to New South Wales.

Photo 5.—T1 Power Station—Tournarockers in the access tunnel.

One of the main advantages of the scheme to the two states is the securing of this power without having to bear the capital cost of otherwise installing thermal plant with its related coal production. They will, however, have to build some large thermal stations to supplement the power from the Snowy hydro stations.

The reason for this is that thermal stations are not well suited to a constantly varying output. To meet peak loads which may not always be predictable it is necessary to have stand-by stations ready, or to run plant at part load. This type of operation is not efficient. On the other hand hydro units are well able to compete with rapid load changes during peak hours as they can be brought into operation or closed down very quickly. The most efficient and economical arrangement is thus a combination of thermal and hydro stations, with the former operating on virtually constant output and the latter being used to meet the peak loads. This is the combination which is being planned and which will make the best and most economical use of Australia's limited water power and good coal supplies.

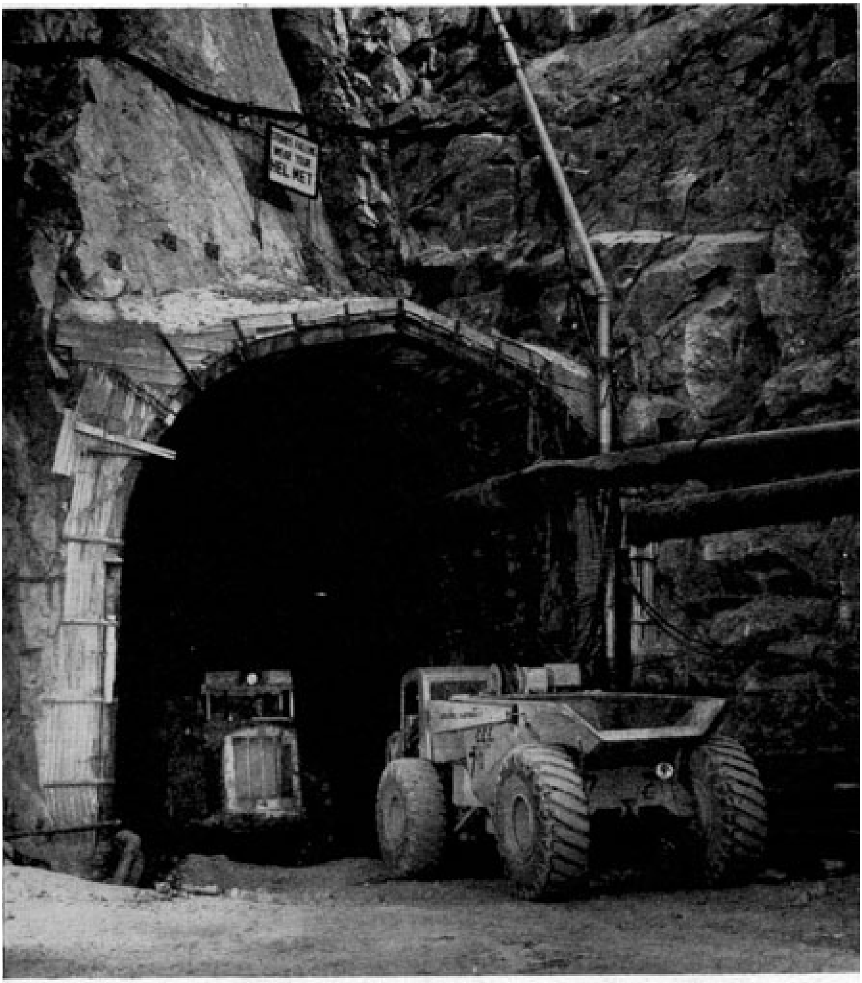


Photo 5.—T1 Power Station—Tournarockers in the access tunnel.

The load factor of the Snowy scheme will be relatively low, at about 24 per cent when completed. The thermal stations will need to be operated at about 80 per cent to satisfy a total system load factor of 55 to 60 per cent. This conforms to the general rule that the increase in energy cost with reduction in load factor is much less in hydro than thermal plants, and the economy of hydro compared with thermal plants becomes increasingly favourable as the load factor decreases.

If thermo-nuclear power becomes economic the same considerations will apply, as atomic power stations will also function best supplying base load.

Furthermore careful examination of the economics have shown that the annual cost of electricity supplied by the scheme will be less than that of meeting the same requirements by the building of more thermal stations.

Overall the total output from the scheme will be kept fairly constant by balancing the variable output from "run of the river" stations like Guthega, which must fluctuate with seasonal changes in flow, with supplementary output from stations operating on flows released as required from the very large main storages such as Adaminaby and Jindabyne.

Mention has already been made of the 33,000-volt transmission lines which will carry the Snowy power to the main load centres of Sydney and Melbourne, between which it is situated roughly midway. This position will enable the scheme to take advantage of the diversity in the power needs of the two load systems.

The Commonwealth Government has priority to obtain power from the scheme for the Australian Capital Territory and for defence purposes. The remainder will be shared between New South Wales and Victoria in the ratio of 2 : 1.

Irrigation Features

When the scheme is completed the fertile plains of the Murray and Murrumbidgee valleys will have gained by nearly two million acre-feet of water, which will enable these areas to produce additional foodstuffs to the value of £30 million per annum. The availability of this water and its sharing between New South Wales and Victoria is detailed in Appendix A (D). The total supply of irrigation water for the scheme represents an increase of 70 per cent on the total present diversions from those rivers and their tributary streams in the two riverine states.

These additional waters will enable more intensive development of areas already reticulated and the extension of irrigation to new high quality lands by new distribution canals and channels, and by pumping. This will have a stabilizing effect on rural production in these irrigation areas.

With the method of operation described above more water will be released from the main reservoirs through the power stations in the dry than the wet season. It is obviously desirable that all water released during the wet winter months when the rivers tend to flood, should be held for irrigation use during the dry summer months. This will be effected by re-regulation in the Blowering reservoir on the Lower Tumut and enlargement of the existing Hume reservoir on the Murray.

The principle that the cost of providing irrigation water from the scheme would be defrayed by charges for power has been previously mentioned. It is estimated that £60 million of the cost of the scheme is attributable to this provision. This unusual feature of the scheme benefits the states by giving them free water, and operates to the disadvantage of the scheme in putting up the cost of its power.

Scientific Services

A scientific services group was established within the authority's organization in January, 1951, with terms of reference "to apply fundamental sciences to the elucidation and solution of engineering problems which cannot be handled by normal methods; and to advise on soil conservation and erosion measures". An extensive engineering laboratory was built up at Cooma, and field laboratories were established near the sites of certain major works.

The types of engineering problems which the scientific services group was called upon to solve fell into the following classes:—

(*a*) *Hydraulic* problems, relating to the design and operational performance of dams, tunnels, underground power stations, turbines, gates, valves, spillways, surge tanks and other structures, and flood control.

(*b*) *Constructional material* problems, concerning the selection and maintenance of quality in service of such materials as concrete aggregates, materials for roads and earth and rock-fill dams, steel for penstocks, and concrete control for strength, durability, impermeability and cavitation resistance.

(*c*) *Structural* problems, such as the relative locations of chambers in underground power stations, the behaviour of penstocks under dynamic loadings, tests in unusual forms of structures, and the behaviour of structures in service.

(*d*) *Investigational* problems regarding engineering geology, soil conservation and earth movements, the analysis of water, sewage, dust and objectionable gases in quarries and underground workings, control of the movement of fish, the application of new scientific aids to the determination of data, and the development of new construction techniques.

Some selected problems which were successfully tackled and which are of general interest are described in the succeeding paragraphs to illustrate the wide ramifications of a huge project like this.

Hydraulic Problems

The removal of all air in the water entering the turbines is essential to their efficient operation. As a result of extensive experiments with models in the hydraulics laboratory a satisfactory design was evolved for removing entrained air from the water entering turbines in underground power stations via the vertical surge shaft. The similar problem of de-aeration of water from surface streams feeding into the Tooma–Tumut tunnel by vertical shafts was also solved. Successful solutions were achieved to both problems by a combination of a syphon or series of syphons and a forced spiral or vertical vortex.

Models again were used to carry out hydrostatic tests of the bifurcates leading water from the foot of the vertical pressure shaft at the T1 power station into the two turbines.

Constructional Material Problems

The climate of the region is such that at altitudes above 5,000 ft. snow persists some five months in each year, and indeed isolated drifts are often found in midsummer at the highest altitudes on south-facing slopes. The minimum temperatures are the lowest in Australia, possibly as low as $-20°$F. at high levels, while the maximum recorded lie between 90°F. and 100°F. Characteristic of the high country are the rapid changes of temperature in the course of a day, and the large number of passages through freezing point. Even in midsummer heavy frosts are common at night.

These climatic factors are of significance in the design of satisfactory concrete mixes for the exposed surfaces of concrete structures. Durability is more important than strength in concrete mixes for these surfaces. Freeze–thaw durability tests of concrete confirmed overseas experience that greater durability could be obtained by the deliberate entrainment of air in the concrete through keeping the water/cement ratio as low as possible and by close control of grading. In comparative durability tests in the laboratory it was found that normal concretes without air entrainment disintegrate or lose 25 per cent of their original weight after 60 to 120 temperature cycles, whereas well designed mixes with air-entrainment do not disintegrate although the surface may fret.

Another investigation concerned the effect of free biotite mica in crushed fine aggregate upon the properties of concrete for the Guthega project. In this part of the region the absence of adequate quantities of natural sand within many miles of the site made it necessary to use a crushed fine aggregate derived from Kosciusko granite: this was found to contain large quantities of free biotite mica, which could not be separated economically from the crushed fines, and some concern was felt about the effect of this on the concrete. Extensive tests determined the increased water requirement in relation to the mica content of the fine aggregate; and showed that the mica content did reduce the compressive strength in proportion to the amount of mica present, but the density of compacted but workable concrete and other properties were not significantly altered.

Engineering Geology

The area covered by the scheme has complex geological features. In brief a mantle of decomposed rock covers the area to a depth of 200 ft. In the southern region granitic rocks predominate, natural sands and gravels are scarce. The northern region is more complex: granitic rocks are extensive, with lightly folded sedimentary and metamorphosed sedimentary rocks and scattered areas of almost horizontal lava flows capping some of the highest ground. This basalt often overlies beds of unconsolidated clay, sand, lignite and gravel. There are numerous faults, shear zones and dykes, many of which are decomposed to considerable depths.

Steep slopes, although favourable for the development of hydro-electric power, together with swamps and old glacial moraines, produce many problems in the construction of dams, power stations and roads. Grazing without controls and burning as a way of improving pastures had already introduced major soil erosion problems in the catchment area.

The activities of engineering geologists have been to determine the geological feasibility of proposed layouts, to isolate geological problems and difficulties likely to be met and to propose solutions for them, and to obtain all geological data required for final designs. This required geological reconnaissance of the whole area, exploration of sites and material sources, by diamond drill, seismic refraction surveys, trenching and test pits, and geological mapping. During construction systematic inspection and assistance with immediate problems was provided.

Among the many activities carried on were investigation of dam sites. It was found possible to find sites for all of the dams in narrow valley sections, generally with steep walls and no alluvial flood plain. Of most interest is the case of the site of the Spencer's Creek Dam, a few miles from the summit of Mount Kosciusko, which is on an ancient glacial moraine. Orthodox methods of dam construction would involve the removal at prohibitive cost of over a hundred feet of porous glacial material to reach a rock foundation. Investigations have shown the practicability of avoiding this by permanently freezing the deposit and building the dam on the frozen ground.

An investigation was carried out of a proposed Geehi Dam, where one abutment of the site chosen was suspect. Upstream of the dam site the mantle of over-burden over the rock appeared too extensive and its lower level too near the river bed to be safe. Under conditions of saturation when the dam was full and subsequently there was a high rate of draw-down such as is necessary to the operation of an associated peak-load power station, it was suspected that the soil mantle of the valley could suffer extensive mass movement which could fill the storage with debris. Exploration of the area in detail by test pits, deep auger holes, seismic refraction geophysical survey and other means, plus laboratory analyses of soil samples led to the conclusion that the factors of safety were reduced by almost one-half under conditions of saturation and heavy draw-down. The results of this investigation led to reconsideration of the whole project, and the proposal to build a dam on this site was abandoned.

These conclusions were dramatically substantiated by a major landslide at the site after an unusually long period of wet weather.

A study was made of the seepage effects on the Tooma Dam, where an unorthodox section was necessary because of the scarcity or cost of certain essential construction materials. Decomposed granite was available in abundance for the core, but transition materials for filter zones were in short supply, so that the latter had to be kept as narrow as possible. Owing to severe draw-down conditions in the storage, the up-stream face of the dam had to be faced with a heavy blanket of rock, but the long haul involved made this method too costly for general use on the downstream face also. Instead, semi-impervious material from the spillway excavation was used which was kept dry by use of a rock drain, leading to a downstream drainage blanket, between it and the core. The study determined that the solution would be satisfactory.

Physical Problems

Tests of steel plate provided by four European steel mills for the Guthega penstock showed that an appreciable number of the plates were made of a steel subject to cold embrittlement. Although the steel was satisfactory according to the terms of the specification at normal temperatures, its strength in terms of load impact values fell off rapidly at the lower temperatures around 32°F. which are often approached in service during the winter at Guthega. A revised authority specification was prepared, to which satisfactory steel was produced by the Broken Hill Proprietary Company to replace the unsuitable material.

Extensive studies of structural behaviour were undertaken in connexion with the T1 power station, the first to be established, to collect data for future design and construction of underground power stations, in which experience is limited. For example, photo-electric studies to determine the stress fields in the rock resulting from the removal of materials at depths approximately 1,000 feet below the surface, showed that over a considerable part of the dividing wall between the machine and transformer halls, planned to be parallel to each other, the maximum shear stress would be nearly parallel to a rock joint plane system as determined by engineering geologists. This could have resulted in a situation of serious difficulty, so it was decided to place the transformer and machine halls at right angles to each other in the form of an L.

Because of the wide span (78 ft.) of the machine hall, the cost of steel sets for roof support would be high. With a view to reducing this cost the use of rock bolts has been developed, and they are now being used extensively throughout the scheme in place of conventional steel sets. Measurements of loads in steel sets and rock bolts have been taken and compared, and model studies have been made to determine the exact mechanism of rock bolting in igneous rocks.

Soil Conservation

The rain precipitation in the region is the highest at this latitude in Australia. It varies with altitude and the average number of rain days per year, but is generally high. Wind velocities are also greater than in most other areas of Australia, and frost action is very severe. These together give rise to many erosion hazards; uncontrolled clearing, burning off and grazing have already contributed their toll, and excavation and other works connected with the scheme can do untold further damage. The preservation of the catchment area is essential to the operation of the scheme and the continued supply of irrigation water to the Murray and Murrambidgee valleys. The objectives of soil conservation are attained by establishing plants on bare soil surfaces to hold the soil against the ravages of water, wind and frost.

One significant phenomenon is the formation of "needle ice" by frost. These are extensive clusters of needle-like crystals of ice which grow normally from the surface of the soil during the night to a length of up to four inches. As the temperature rises during the day, partial melting causes small masses of this needle ice to break off, and if on a slope to fall taking with them particles of soil adhering to them. It also actually lifts young seedlings out of the ground. This needle ice although limited in extent, has been found to be a major factor contributing to soil erosion on bare slopes created by excavation work.

Conditions governing its development are being studied with a view to developing counter-measures should serious erosion occur, especially where it is anticipated around some storages where all vegetation is killed by submergence but will be exposed for varying periods when water levels are low.

Marked differences in temperature, as much as 15°F. between the valley floor and adjacent ridges a few hundred feet higher, are common, and result often in slopes being covered to a definite level with one group of plant species and above with an entirely different group. Normal methods of sowing grass seed in the region are not generally successful: at higher levels the autumn sowing often fails owing to needle ice activity before the grass is properly established, while spring and summer sowing is unsatisfactory owing to heat and dryness. An effective but costly way is to use grass sod strips cut from flat easily resown areas to provide a continuous cover on bare earth surfaces. The amount of satisfactory grass sod in the Snowy Mountains is limited, and the costs are high with long haulage and wastage during handling. Experiments have been made with "prefabricating" grass sod by sowing seed into a layer of soil placed on an impervious material, which forces the roots to form a strong mat which can be rolled up without cutting. Initial trial results of this method are encouraging.

Another approach is by sowing and then protecting the grass seedlings by an insulating blanket until they become well established. The aim of this blanket is to hold the soil and seed in place, as well as to prevent the formation of needle ice and to provide some protection against desiccation. One method of providing this blanket is by straw lightly sprayed with an asphalt emulsion. This method is in use in the U.S.A. and offers possibilities of reducing the costs of the treatment by mechanization of the process.

Defence

Besides the general purpose of building up the strength of the Dominion in power resources, industry and primary production in the interests of national defence, the scheme has features which will add to its value from the defence viewpoint. Thermal power stations, which are particularly susceptible to attack, are mostly in exposed positions near the coast line or the principal cities which may be targets of enemy attack. The hydro stations of the scheme are, however, tucked away underground or in deep valleys in a remote mountain region, where they will be very difficult to put out of action by a concerted attack. Even destruction of the dams would only result in a reduction in the amount of controlled energy available, and would not put the stations completely out of action.

The geographical position of the scheme midway between Melbourne and Sydney enables it to support the load of either if one was damaged by enemy attack. The transmission lines to these two cities would also permit the establishment of dispersed industries in areas traversed.

Savings in manpower can be effected in abnormal times by relying more upon power from hydro than thermal stations: the production of power from the latter, including coal mining and transport, requires about forty times more manpower than the production of the same quantity of hydro power. The huge volumes of water which will be held in the main storages will be a reserve of potential hydro power to draw upon in the event of catastrophe overtaking the thermal stations: thus the stored energy in the Adaminaby reservoir when full will amount to approximately twice the total annual consumption of energy in New South Wales.

In the event of a war involving Commonwealth and Allied forces in South East Asia, Australia would again be a main support area, and a base for the supply of those forces. Besides the output from her secondary industries, boosted by Snowy power, the additional foodstuffs produced as the result of irrigation with Snowy water will enable her to discharge this responsibility even better than in the last war.

Appendix A

TABLE OF PRINCIPAL FEATURES

A. Main Storages

Dams	Height	Volume of fill	Approximate net storage capacity
	Ft.	Cu. yds.	Acre ft.
Adaminaby..	390	9,500,000	3,500,000
Jindabyne	274	3,700,000	1,100,000
Tantangara	200	1,750,000	500,000
Tooma	222	1,400,000	22,400

B. Main Diversions

Tunnels	Length	Diameter
	Ft.	
Eucumbene-Tumut ..	72,860	21 ft. diameter (lined) (under construction)
Snowy-Murray—		
Snowy-Geehi	96,000	Not yet determined
Geehi-Murray	53,000	Not yet determined
Tooma-Tumut	47,000	14 ft. diameter (mainly unlined)
Murrumbidgee-Eucumbene	54,900	12 × 10 ft. (mainly unlined)

C. Power Stations

Station		Capacity	Average net head	Average flow	Total Length headrace plus tailrace tunnels	Headwater dam	
Name	No.	kW.	Ft.	Cusecs.	Ft.	Type	Ht. Ft.
Spencer's Creek	M1A	60,000	555	248	14,400	Earth	90
Guthega	M1B	90,000	800	410	14,500	Gravity	110
Island Bend	M2L	60,000	415	450	15,500	Gravity	145
Finn's River	M2H	10,000	605	28	5,000	Earth	50
Island Bend Shaft	M3	265,000	900	770	1,000	Arch	143
Windy Creek	M4	75,000	1,775	127	6,700	Gravity	110
Geehi Shaft	M5L	20,000	145	655	2,500	Gravity	276
Geehi Pond	M5H	40,000	285	320	11,800	Gravity	80
Bogong Creek	M6	540,000	950	1,710	21,200	Arch	296
Swampy Plain	M7	540,000	930	1,820	34,000	Gravity	180
Upper Tumut River	T1	320,000	1,065	1,300	12,000	Arch	290
Upper Tumut River	T2	280,000	863	1,420	36,200	Gravity	140
Lob's Hole	T5	180,000	220	1,680	—	Earth	245
Cumberland	T6	230,000	378	1,800	14,900	Earth	300
Blowering Dam	T7	60,000	195	1,880	—	Earth	250

Note 1. Where structures not yet under construction are referred to, the dimensions and data are tentative only and subject to revision on more detailed investigation.

Note 2. Initial capacity at present installed in Station M1B is 60,000 kW. Dam heights are height from river-bed to crest of dam. Total length of headrace and tailrace tunnels includes length of tailrace surge chamber.

D. Water Available for Irrigation by Diversion and Regulation

1. *Gross diversion quantities*	
Snowy at Jindabyne to the Murray	722,000 acre-ft. per year
Snowy's tributary the Eucumbene to the Tumut	248,000 acre-ft. per year
Murray's tributary the Tooma to the Tumut ..	280,000 acre-ft. per year
Murrumbidgee to the Tumut	280,000 acre-ft. per year
Total ..	1,530,000 acre-ft. per year
2. *Gain to Murray by diversion and regulation*	
(*a*) Due to diversion from Snowy to Murray	722,000 acre-ft. per year
Less diverted from Murray to Tumut ..	280,000 acre-ft. per year
Net gain due to diversion	442,000 acre-ft. per year
(*b*) Due to regulation	356,000 acre-ft. per year
Total ..	798,000 acre-ft. per year
3. *Gain to Murrumbidgee by Diversion and Regulation*	
(*a*) Due to diversion from the Eucumbene and Tooma	528,000 acre-ft. per year
Due to regulation	492,000 acre-ft. per year
Total ..	1,020,000 acre-ft. per year
Total gain to Murray and Murrumbidgee	1,818,000 acre-ft. per year
4. *Sharing of water by New South Wales and Victoria*	
(*a*) N.S.W. from Murrumbidgee	1,020,000 acre-ft. per year
from Murray	520,000 acre-ft. per year
Total for N.S.W.	1,540,000 acre-ft. per year
(*b*) Victoria. From Murray	278,000 acre-ft. per year

Bibliography

Grateful acknowledgement is made to the following publications, which have been quoted or used in the compilation of this article:—

The Snowy Mountains Scheme by Sir William Hudson, K.B.E.

Engineering Geology for the Snowy Mountains Scheme by D. G. Moye, B.Sc.

Hydrology in the Snowy Mountains Area by E. B. Pender, B.A., M.E., D. T. Walsh, B.E., and D. Anderson, B.A., B.A.J.

The Snowy Mountains Scheme and the Application of Scientific Services by T. D. J. Leech, C.B.E., B.Sc., B.E.

The Snowy Mountains Story and other publications of the Snowy Mountains Hydro-Electric Authority.

Whither the Corps

By Brigadier J. B. Brown, B.A., A.M.I.C.E.

Introduction

"*The influence which the Corps of Royal Engineers can exert on the policies of the Army, and the weight which its recommendations carry in the councils of the Army, depend directly on the status and prestige of the Corps as a whole, and these in turn depend directly, and almost entirely, on the professional skill of its members.*"

The implications of this statement merit the most serious consideration by all members of the Corps, and by the other branches of the Service. The Corps of Royal Engineers, having lost the responsibility for Works Services, stands at possibly the most vital cross-roads in its history. It is in order to examine this problem that this paper has been written.

The Corps exists to provide engineer services of various kinds including advice for the Army in peace and war. If those services are not required or are modified by the passage of time, then the reason for the existence of the Corps disappears or is modified also. If, on the other hand, these services remain vital to the Army then the Royal Engineers must provide them to the best of their ability, and will be judged by results. Consistently good results can only be obtained if professional skill and ability are present.

The manifestations of the professional skill of the Corps are diverse. Amongst its many examples are:—

Group I	Civil and structural engineering. Electrical and mechanical engineering.
Group II	Field Engineering.
Group III	Transportation. Survey. Postal.

It is with the first two groups of these that this article is concerned. This is not to deny in any way the importance of the third group, but they have not been affected by the loss of the Works Services. It is now well known that, as the result of the recommendations of the Weeks Committee, the Army Works Service is being taken over by a civilian organization and with this transaction the Corps has lost an opportunity to practice building construction and civil and E. & M. engineering in peace. It is vital, therefore, to examine what this loss means and to consider what must be done to replace it.

The Past

As a start it is interesting and instructive to consider the Charter of the Institution of Royal Engineers and also something of the history of the Corps.

The Charter lays it down that the purpose of the Institution is: ". . . the general advancement of Military Science and more particularly for promoting the acquisition of historical and scientific knowledge in relation to Engineering as applied to military purposes." It does not require much rewording to convert this into a definition of the *raison d'être* of the Corps.

The Royal Engineers re-assumed* responsibility for the building of barracks in 1822, "under the particular direction of the Duke of Wellington." In 1862 the Secretary of State for War appointed a Committee to "consider the measures that should be adopted in order to simplify and improve the System . . ." This, of course, was the first of several occasions when the Army became dissatisfied with its Works Services. The interesting fact which emerges from this Committee's report was the unanimity with which the witnesses agreed that it was necessary for the Royal Engineers to continue in charge. Sir John Burgoyne, who was Inspector-General of Fortifications, gave evidence as follows (*inter alia*): " . . . The impression of the Duke of Wellington was, as I recollect, at the time (1822), that the Royal Engineers might be turned to very good account for the service of the barracks . . . It has the very great advantage of keeping the officers of Engineers employed, and turning them to profitable account, when they must be maintained for the good of the service for a time of war, and as a component part of the Army; . . . and employing them upon barrack duties gives them a great deal of knowledge of their profession, . . ." (This view was supported by others.)

This period, up to the end of the century, was perhaps the hey-day of big engineering projects, particularly in India and the colonies. Whilst at home and overseas the building of barrack accommodation was going on, other Sappers were leaving permanent memorials to the Corps in the form of major engineering works, frequently of a development nature. For instance, much of the present day knowledge of irrigation canal engineering is due to the work of Sappers. Similar work was being done with roads, railways, drainage, and in other ways. One can only be filled with envy of the opportunities available in those days as one reads of the work in India described in *The Military Engineer in India*. One lesson perhaps stands out. All these officers designed their own work, and this is one of the great deficiencies today. How many Sappers today can say that they have designed anything of any importance?

In consequence, the Corps was technically in a very strong position when the South African War broke out, and in which considerable demands were made on its professional engineering skill. At the end of this war it emerged with an enhanced reputation, much increased in size and, as is usual on these occasions, became the object of considerable jealousy amongst the rest of the Army. As a result when the inevitable demand came for a reduction in the size of the Army, the Corps came under the heaviest fire of all.

The Esher Committee was appointed in 1903 to examine the matter, and took evidence voluminously. It was suggested by some witnesses that an engineer unit was more expensive than any other, both to train and maintain, and that since there was insufficient time to learn both its military duties and

* The first barracks were built in 1704 and the following years by the Royal Engineers under the Board of Ordnance, mostly in Ireland. In England by 1792 only sufficient accommodation for 20,000 men had been built, and probably due to impatience with results, responsibility was handed over to the Deputy Adjutant-General. By ignoring all financial control this officer (a cavalryman) built, between 1792–1822, accommodation for 17,000 cavalry and 146,000 infantry. Soon after 1792 responsibility for barracks for engineers and artillery was restored to the Board of Ordnance and the Royal Engineers. Brompton Barracks was amongst these and was originally built for artillery.

its building work the latter should be handed over to architects whose training fitted them for the task. This view was countered by a body of opinion which urged that the work of the Royal Engineers in war required considerable knowledge of the use of materials and engineering practice and technique. The Esher Committee, while accepting this argument, recommended that a civilian Director of Barrack Construction and an entirely civilian department be formed to build new barracks. This modified form of the proposal persisted until 1917 when it was abolished, having in fact accomplished very little; the barracks at Tidworth and the hospital at Millbank being its chief memorials. Nevertheless the effect on the Corps was almost certainly to reduce its opportunities to practice civil engineering.

There have, of course, been innumerable other committees, notably the Sandhurst Committee in 1886 and the Kitchener Committee in 1911, which covered very much the same ground.

Consideration of the proceedings of these Committees suggests two salient features:—

(*a*) The almost universal agreement amongst Royal Engineers that Works Services were essential training for war.

(*b*) The almost equally universal undercurrent of dissatisfaction in the Army with the accommodation provided, and the tendency to blame the Royal Engineers in consequence.

Before endeavouring to draw any lessons from history, the background to the Weeks Committee, which has finally removed Works Services from the Corps, must be examined. This Committee came into being, not because the Army was voicing its dissatisfaction with Works Services, but because those who had to operate the Works Services system were driven to desperation by the frustrations and the difficulties. Nevertheless it would be dangerous to assume that history was not repeating itself. The Weeks Committee liberated a great deal of hitherto unexpressed dissatisfaction, and much of it was directed against the Royal Engineers. This criticism was mostly grossly ill-informed and completely ignored the financial facts of life, and of course the ever-changing policy which effectually prevented much vital building being started. Some of the criticism was also malicious. There is, however, a grain of truth lurking amongst the chaff, and for various reasons the Corps is not entirely blameless for the defects in the Works Services.

Of course, since the divorce of Quartering from the Works Directorate, the latter has had less say in the policy than it had pre-war. This follows the modern trend of not allowing the engineer to have control, and whatever the results may be for the organization, the position of the engineer is bound to suffer, and he will have decreasingly less say in the management. This unquestionably happened to the R.E. Works Services.

The important facts which emerged from the Weeks Committee are:—

(*a*) It exposed unconsciously the fundamental paradox of Works Services being done by Royal Engineers, which is that Royal Engineers are concerned with civil engineering and its applications in war, for which they are trained, whereas the provision of barrack accommodation in peace-time is largely an architectural problem, for which Royal Engineers are not trained. This may well be one of the basic reasons why the Army during the last 100 years has somewhat inarticulately expressed its dissatisfaction with its accommodation.

(*b*) It has lent emphasis to the fact that civilianization of Works Services has already gone so far that very few Royal Engineers are properly employed in the engineering skills for which they are trained.

(c) The Army as a whole, and many members of the Corps, either do not realize the implications of losing Works Services or, unlike their predecessors, do not think it matters.

Before attempting to draw deductions from the past, it is necessary to go back once more to the 1862 Committee. Amongst their recommendations were the following:—

"81. The Committee are of the opinion that young officers of Engineers leaving the School of Instruction at Chatham, should invariably be posted to stations where large works are being carried on, and where they will be under proper superintendence."

"82. The Committee recommend that arrangements should also be made to enable officers who, during their course of instruction at Chatham, are found not to possess sufficient aptitude or inclination for the duties of an Engineer, to enter some other branch of the military profession, in consideration of the examination they must have passed to obtain their commissions in the Corps of Royal Engineers."

Clearly, in the opinion of many of the witnesses, and of the Committee, a Royal Engineer must be an engineer. There was clearly also a trend even then for the Corps to divide into engineers and military engineers.

What can be deduced from the past?

The first thing to be considered is the extent to which Works Services is, or was, of value to a Royal Engineer. An engineer needs experience of handling materials, and plant, he needs experience of doing things, and he needs design experience.

In the early days not only did the Royal Engineer assume responsibility for buildings, he also built fortifications, an engaging and useful task with engineering implications, which has in recent years died away. Since the building and contracting industry was practically non-existent, he was frequently called upon to solve many engineering problems which are now solved by the contractor. Abroad he had even greater responsibilities, for example, railways and canals.

Above all he did his own designing, an essential element in the experience of the whole engineer.

Since 1903 the tendency has been to give much of the work to civilians, and since 1945 this tendency has been accelerated. Much valuable designing experience has been lost through the employment of outside consultants, and even in the D.F.W. Directorate there are few engineer officers being used as engineers. In E.12 (Civil and Structural) where some Sappers could logically be employed there are none, and in E.13 (E. & M.) there are, at present, five, of whom only two are Regular officers. The same general trend is true throughout Commands. In consequence, a Sapper officer in general tends to be a planner and co-ordinator of other people's activities, and on the ground a supervisor of other people's designs. Moreover, except in the more senior appointments, the officer is seldom a Regular one. In effect, therefore, the Regular officer seldom gets a close-up of work on the site. Increasingly, therefore, the Sapper has become an engineer who has had a good technical training but never had the opportunity to try out his own designs, and has become the poorer in consequence. This has had two results, first the necessity to consult experts instead of being able to give an opinion founded on experience, a vicious circle, and secondly the drift of many able brains away from the Corps, or from the engineering activities of the Corps, because there are no longer enough engineering opportunities available.

It must be admitted at once that the load of work and the shortage of man-power has forced the Corps to go outside for help; nevertheless, with the exception of a few projects like Christmas Island, the tendency has been to unload the interesting engineer projects, and to remain in the administrative role. There is also no doubt that a number of engineer projects of great value could have been undertaken by Engineer units but were declined for fear that it would interfere with training. Whether this decision was right must be considered.

To sum up the past it can be said that employment in Works Services has provided valuable experience in the design and construction of projects, but that the tendency has been for opportunities to design to have decreased to disappearing point.

Secondly, that a number of officers have acquired valuable knowledge and practical experience of site work and contractual procedure, and in a few cases of the planning of major projects, but that these experiences have been confined very largely to more senior officers, and that the junior Regular officer is unlikely to obtain Works experience until he is a major. From the point of view of engineer training this is dangerously late.

A relatively few officers have been on a long engineering course.

The Present

Before considering how to apply the experience originally provided by Works Services, and how to make good the deficiencies in that education, it is necessary first to consider whether a military engineer needs to be a civil engineer at all. (The term civil engineer is used here in the collective sense to embrace structural and E. & M.) The policy of the Corps has always been that its officers must be engineers, and that its other ranks must be tradesmen, but any dispassionate appraisal of the present problem must re-examine this aspect, particularly since there is a school of thought which would separate the Corps into field engineers and civil engineers.

The peace-time organization of the Corps is largely that of divisional engineers with a small proportion of Corps engineers, and training tends to be devoted to the field aspects of the work which the division will require. There is inevitably, therefore, a reluctance to think in terms of "civil" engineering, and indeed, in spite of the lessons of two world wars, there are many people, including Sapper officers, who think of the Corps entirely in terms of divisional engineers. There is, of course, no doubt that in any major war the proportion of divisional engineers to other engineer units is very small. It is also true to say that the work of divisional engineers can be divided into two categories, equipment engineering and basic field engineering. The former, which includes bridging, demolitions, mine laying and lifting, and water supply in the field, and which is popularly imagined to be the sole work of divisional engineers, can in fact be carried out, and has been carried out, by any unit which has been trained in them. The minimum of engineer knowledge is required. Basic field engineering, e.g. roads and tracks, forward airfield construction, improvised bridging, defences, begin to make demands on basic engineer knowledge, and the less equipment there is available, and the more improvisation becomes necessary, the greater becomes the demand on engineer knowledge.

It will be within the memory, moreover, of those who served with divisional engineers in the last war, that they were liable to find themselves faced at very short notice with engineer problems of considerable magnitude, for instance getting a town's services going, whilst behind the division the work of engineer units becomes increasingly akin to that of civil engineers, with the added difficulties that war brings of shortage of time, materials and probably men, not to mention enemy interference. It will not be necessary to enumerate the categories of engineer work in which the Corps will be involved; to mention only communications, airfields, accommodation, docks and water supply, is sufficient to indicate the vastness of the field.

It may be argued that the engineer knowledge required will be provided from industry, mobilized at the beginning of a war, but this is a very dangerous philosophy. It has been proved in two world wars that the Regular officer and the civilian engineer are complementary and not supplementary, and that the best results are only obtained if the two categories speak the same engineering language. They then understand and respect each other and become interchangeable.

Assuming for a moment that the Regular Army provides the divisional engineers, and the civilians the Corps and Army engineers, who provides the senior engineer appointments? And in what respect would they be held by the other category? And assuming they were divisional engineers by training, how good would their advice be on "civil" engineer matters.

Even in a major war, therefore, there seems to be no good reason to recommend a change of the policy that a Sapper must be an engineer, and in the more likely case of limited war, or cold war activities, the Regular engineer unit is not only going to be on its own, but is much more likely to be concerned with "civil" engineering than it is with field engineering.

It is, therefore, unfortunate that engineer units have to spend so much of their time training in field engineering to the detriment of their "civil" engineering. This affects the young officer who, between the time he ends his Y.O. course and the time he goes on a long engineering course or the Staff College, probably forgets more than he learns. Even if he is lucky enough to be concerned with some project of engineering significance his chances of designing anything of importance are extremely small.

The other rank is also affected. It is generally agreed that he must be a tradesman, and yet once recruited and trained in a trade he is hardly ever exercised in it. This is inevitable in a unit which devotes the majority of its time to field engineering, but it weakens the attractiveness of the Corps to the young man of today in comparison with Signals or R.E.M.E. The high quality young man, who is the man the Corps needs, wants to learn a trade, and to be able to call himself an engineer. He is reluctant to come into a Corps where he will not be employed in a trade. Much is made of the fact that there is not time for field engineering training alone, without attempting anything else. It is for consideration whether the high quality tradesman could not make light of field engineering. Once having met the heavy girder bridge, or experienced the "drill" of mine lifting, he would have no difficulty in picking it up again. There is a considerable case for the argument that too much of a fetish is made of field engineering training.

The Future

Where does the future of the Corps lie? Surely all history, not only that of the Royal Engineers but of other arms as well, teaches that unless a Corps is skilled it will cease in time to exist because there is no longer any reason for its existence, and its functions can be taken over by other arms. On the road to extinction it will gradually be listened to less and less, and the quality of its entrants, both officer and other rank, will fall off because the best are no longer attracted. There is some possibility that the Corps has one toe on this road already.

History teaches that the Royal Engineers must be a Corps of engineers and tradesmen. It also teaches that over the last fifty or so years the general trend has been that the Corps has been untrue to itself, a trend which has been reversed by the influx of civilian engineering blood during major wars, but resumed again in peace. This trend may be expressed in that overworked expression: "A soldier first, and an engineer second", which has led to a distinct cleavage between the field sapper and the works sapper, and to the former frequently not being an engineer at all.

The problem therefore is, now that the Works Services no longer belong to the Royal Engineers, to ensure that officers and men get the training and the experience they need as engineers. Turning back to the evidence of Sir John Burgoyne in 1862 in which he quoted the Duke of Wellington, he pointed out that there is a considerable problem in employing Royal Engineers fully in peace, and recommended Works Services as the answer. In those days engineering was simpler and experience in Works Services sufficed. Moreover, as has been mentioned, there were excellent engineering opportunities abroad. This is no longer so to the same degree, and opportunities have got to be looked for unceasingly.

It is intended that 180 officers and 370 other ranks shall be attached either to the new Works Services Organization or to civil consultants or contractors. Is this enough?

The "whole" engineer needs design experience, practical experience on the ground in a variety of problems, and finally experience of handling large projects or groups of projects. It must be appreciated that Chief Engineers of Commands in the future will be entirely divorced from Works, and will have no experience, normally, of any big engineering project. These qualifications are fundamental and they are not easy to obtain.

Design. The big problem is going to be to obtain the opportunities. Design as a E.E.W.T. is not a stimulating exercise, and unless it is allied to the subsequent construction will teach only part of the lessons available.

The new Works Organization is proposing to do all its planning and designing in the War Office and subsequently for the designers to exercise general supervision on the site. The new civil and structural engineers and E. & M. branches offer excellent opportunities for officers up to the rank of major under the supervision of qualified engineers. They will be concerned with the design of external services, with the structural and E. & M. assistance always rendered to architects, and occasionally with a sizable engineering project. For those who are to be attached to civil consultants or contractors design opportunities should be available, and in fact it must be part of the curriculum.

In addition to the actual designing, which all young civilian engineers do before they can qualify for their institutions, they have to learn to take off engineering quantities and prepare specifications. This is not difficult to learn and it is a great pity that Royal Engineer officers have never been taught these subjects, since they force the engineer to examine his design in detail from a fresh viewpoint, and enable him to assess materials required and also by breaking the project down into operations to examine the problems of construction and the time factor.

Practical Experience. Some officers will have the opportunity to exercise general supervision of their own designs whilst working for the new organization in the War Office, but this is not enough. The realities of engineering life are only brought home through daily contact with them on the site, and therefore the attachment of as many officers as possible to consultants and contractors is essential.

The new Works Organization intends to obtain its resident engineers and clerks of works for Part I Services, either from its own central pool or, as is done in civilian life, by temporary engagement. They will not, as is done at present, be part of the Command staff. The Corps, therefore, must endeavour to obtain a good share of these resident engineer jobs. Since the staff of the new organization in commands will only be concerned with Part II and Part III work there will be very little of value to be obtained for the R.E. officer in the general run of appointments, and they should be avoided as far as possible.

Provided that the object is kept clearly in view, that is to say gaining genuine engineer experience, there will be little difficulty in obtaining it for officers up to the rank of (say) Major in the fields of design and practical site experience. The great problems are going to lie in:—

(*a*) Continuity of training.

(*b*) Experience of large scale engineer organization and administration.

Continuity of Training. Provided that an officer's career is planned from the start he should be able to do two tours as an engineer on the lines suggested above. In between these tours he will have returned to a unit, and it is important, if the Corps as a whole is to become more engineer minded than it is at present, that young officers should have experience of engineer units engaged in engineering. This aspect will be touched on later. Moreover, as far as possible an officers' engineer training should be continuous and also, if made use of, his experience will be of value to the unit.

Experience of Organization. This is going to be extremely difficult to arrange for senior officers, and unless a satisfactory solution can be found a serious gap will be left in the abilities of the Corps.

Provided engineer regiments can be used on major projects it will be possible to exercise Lieut.-Colonels in organization and control on a large scale, and a very few officers of this rank or the next above may get opportunities on future Christmas Islands or with consultants, but the training of Chief Engineers will probably be confined to occasional E.E.W.T.s.

Training of Engineer Units. It has been shown that engineer units must be trained to a greater extent than at present in civil engineering, not only because the unit needs the training, but because the officers need the experience of major projects, and the senior officers the practice in control and organization, but also because the tradesmen need exercising in their trades.

The engineer unit can function in one of two ways:—

(*a*) *As a contractor*. In this case the design will be done by an outside agency, e.g., the new Works Organization. Nevertheless, the contract should be regarded as "negotiated" and the unit should be represented in the design team. This will help to give design experience, to keep the "contractors'" viewpoint to the fore, and enable him to take early preparatory action as the designing proceeds.

(*b*) *As an all-in service*. Here the regiment is provided with the requirement, and functions as consultant and contractor. The unit will conduct all negotiations with the client to establish details, and possibly with other interested authorities. It will prepare all designs, order all stores and carry out all work. It might be necessary to prepare estimates of cost as well, and it would certainly be a useful and salutary exercise.

Projects of this sort will probably necessitate strengthening the unit temporarily. Additional staff officers may be needed, and additional design and supervisory staff. Care must, however, be taken that these additions do not deprive the unit of valuable experience. Unit officers should as far as possible do their own design and unit N.C.O.s ought to be able to supervise their own tradesmen.

It is quite obvious that opportunities for this kind of training will have to be looked for, and obstacles overcome. It is always being said that in the U.K. there will be trade union objection. Is this anything more than what was once a prophecy, which by constant reiteration has grown into a law?

The interference with field training will also have to be considered in an unprejudiced light. It may well be that divisional engineers can afford less time than Corps or construction regiments, but engineering and trades training are of such fundamental importance that every effort should be made to undertake such tasks at least one year in three. Corps and construction regiments (at present non-existent) should obviously do more. It also seems possible that the proportion of Corps and construction regiments should be increased at the expense of divisional regiments, so that more civil engineer training is done throughout the Corps.

Other aspects of training

This article has tried to emphasize that a fundamental re-assessment is needed if the Corps is not to deteriorate, and that increased emphasis on engineering is needed. This will need a completely altered mental outlook for many, and for all it will be necessary to keep engineering in the forefront of their minds. Some of the following should be considered:—

(*a*) *Professional papers*. At the beginning of this paper is a quotation from the Charter of the Institution of Royal Engineers. To what extent does the Institution fulfil this purpose? A journal is printed at quarterly intervals. How many articles in it are concerned with "engineering as applied to military purposes"? The proportion is low, and is perhaps symptomatic of the decreasing engineering skill of the Corps.

Professional institutions, but not that of the Royal Engineers, have regular meetings at which papers are read and discussed and the proceedings are printed in the *Journal*. In the case of the Institution of Civil Engineers, for example, the paper is printed beforehand in the Journal so that those proposing to attend the meeting can read it. At the meeting the author introduces it briefly, and it is then discussed. The discussion is printed subsequently in the next Journal. The Institution of Royal Engineers could well do likewise. It might also adopt the idea of regional branches of the Institution.

At these meetings, however, engineer subjects must be discussed, and in the early days, until engineering has begun to regain its importance, military subjects should be limited.

(*b*) *Professional Status*. At present the membership of the Institution of Royal Engineers carries no professional status. This has considerable disadvantages at times when dealing with civilian engineers. The Royal Engineer may have considerable engineering ability; on the other hand he may well have forgotten all he ever learnt. There is nothing to indicate which, and the tendency in consequence is to lower the standing of the Corps. Taken by and large the Army and the outside world expect the Corps to be engineers, and their estimation goes down if the expectation proves unfounded.

Membership might be divided into two classes, Associate Membership for all officers who wish to join, and full membership for those with technical qualifications. The qualifications should be partly theoretical and partly practical experience. The theoretical qualifications should be obtained either by an examination set by the Institution or by exemptions provided by a university degree. The practical experience must be, to a very considerable extent, "civil" engineering.

(*c*) Bearing in mind the purpose for which the Institution was formed, the Corps should consider in what other ways it can help to strengthen the professional life of the Corps, possibly in conjunction with the School of Military Engineering.

(*d*) *The young officer*. Under present arrangements an officer can hardly hope to obtain an attachment to gain engineer experience until late in his captaincy. There is, therefore, a vital period after he leaves the S.M.E. when he must have some practice as an engineer if he is not to tend to become interested in regimental life only. Any officer who wishes to be an engineer should have the chance to do so. There are only two ways to do this, either to regard immediate posting to a unit as unnecessary and to send the young officer off at once on an engineering appointment, or to ensure that he is posted to a unit which will be employed on engineering.

(*e*) *Research and Development*. This is now concentrated largely in the hands of M.E.X.E., but is a most valuable form of engineer training on which R.E. officers and O.R.s should be employed as far as possible. It is for consideration whether more could be done in the S.M.E. or whether attachments could be made to the Road Research Laboratory or similar organizations.

(*f*) An article such as this would be seriously deficient if it made no reference to quantity surveyors who have been an integral part of the Corps for so long. It is proposed that a small number remain and be attached to the new Works Organization. It is for consideration whether they would not be useful to an engineer unit employed on a major project, particularly where accounting is required, and therefore measurement is needed.

There may be other opportunities, including instructing in quantities at the S.M.E., but it appears to be necessary to accept reluctantly that military quantity surveyors are required to a limited extent only.

CONCLUSION

The times when the prestige of the Corps has been at its highest have been when there have been opportunities for major civil engineering, and when these opportunities have been taken by the Corps on its own. A vast amount of work was done whilst the Empire was being developed in the nineteenth century, followed by that of the three major wars of this one. As this century has proceeded, however, due to various pressures the tendency to become soldiers first and engineers afterwards has become increasingly marked. Where once the Royal Engineers were amongst the leading engineers of their day, today they compare unfavourably in technical knowledge and experience with their civilian colleagues.

The Corps is, therefore, at a cross-roads and must decide which way to go. On the one hand is the choice of increasing the general level of professional knowledge and ability as civil engineers, on the other to accept the present situation. If the Corps agrees that the path to prestige and strength lies through technical ability, it will seek out every opportunity to gain experience, even to the extent of abandoning part of the divisional engineer function in peace-time.

If, on the other hand, the choice is to accept the present situation, the final result must be fully understood and accepted too. Without the Works Services engineering opportunities will be few, unless they are looked for, and the Corps will be more and more occupied with field engineering, and those with engineering knowledge in the units will grow less and less. In consequence candidates with a desire for engineering will look elsewhere, as will ambitious tradesmen. The final result of this vicious circle is inevitably a Corps of specialized pioneers, and not engineers.

Finally it would be as well to realize that the normal work of engineer regiments in peace-time makes very little impact on the Army as a whole, whereas that of the Works Services made, for good or ill, a very considerable one on every unit and every rank.

The status which a Corps attains has a direct bearing on the importance attached to its advice. In war, or in peace, if too little weight is attached to engineer advice, the result can be disastrous.

If, therefore, the Corps is to carry the weight that it should, it must be known and respected, and this can only come about through carrying out important engineering projects.

EDITOR'S NOTE. This article was discussed at the Engineer-in-Chief's Conference and extracts from the discussion will be printed in the March 1959 *R.E. Journal*. Written contributions to the discussion from members will be printed at the same time and should be submitted to the Editor by 15th January, 1959.

The Great Retreat

By LIEUT.-COLONEL R. A. LINDSELL, M.C.

We travelled in the print of olden wars;
Yet all the land was green;
And love we found, and peace,
Where fire and war had been.
R. L. STEVENSON.

INTRODUCTION

ONE hundred and fifty years ago Sir John Moore led his army back over the snow-clad passes of Galicia to Corunna.

Being stationed in Gibraltar, it seemed an appropriate opportunity to follow in his footsteps and to attempt to recapture at first hand something of this memorable and controversial operation.

This decision involved some preliminary study of the campaign and it was whilst engaged on this absorbing task, that I became aware of the intense criticism of the military engineers in this campaign by the great majority of historians. A typical comment is made by that great contemporary historian Sir Arthur Bryant in his *Years of Victory*, where he writes that during this campaign Moore "had not been well served by his engineers". This appeared to me strange, in view of the unquestioned ability of some of the Sapper officers involved, Richard Fletcher being the C.R.E., whilst the names of both Pasley and Burgoyne are to be found in the list of engineer officers, who took part in these operations.

With a view to examining the causes of this, I decided to review this campaign with particular reference to the work of the engineers and the results of my rather cursory and wholly unscientific researches are with some trepidation set out in this article.

BIBLIOGRAPHY

I do not propose to bore the patient reader with a list of references, but it is of interest to note that two Sapper officers have left us their reminiscences of these campaigns.

An account of the war in Spain and Portugal by Lieut.-Colonel John T. Jones, R.E., was written in 1818 and provides a straightforward and factual account with a disappointing lack of technical detail. *Under England's Flag* by Captain Charles Boothby, R.E., provides a much more readable account, consisting mainly of extracts from his diary. Boothby had only been commissioned some three years before the Peninsular campaign began and his diary shows him to be an intelligent and thoughtful officer with an innate capacity for enjoying himself. I cannot resist quoting a thoroughly irrelevant extract from his account of a road reconnaissance undertaken prior to the advance into Spain in early October 1808:—

"I was directed to the house of the steward of the Marquis de Portachio at Zagdala and was comforted to find it a most capital place—the picture of cleanliness and convenience. I was even more delighted, when his beautiful wife entered the room, with long black mantilla, brilliant rolling eyes, Roman nose, sweet mouth and jet black hair in short graceful curls upon her neck. Tall, polite, retired, conversable, I could not take my eyes off her during supper and feared that my host would cut my throat."

Unfortunately Boothby was detached for a special reconnaissance of the Vigo road early in the retreat, but came round to Corunna by ship in time to witness the final battle.

Historical Background

On 6th October, 1808, Sir John Moore had been appointed to the command of the British forces in Portugal with instructions to support the nationalist armies in Spain. Reinforcements from England under General Baird were dispatched to Corunna with instructions to join him as soon as possible. Due to lack of transport and poor communications, it was not, however, until 3rd December that Moore was able to complete the concentration of his main army at Salamanca, whilst Baird's force was at Astorga, some 150 miles to the north. During this time, Napoleon at the head of a large and well equipped army had smashed the Spanish forces opposed to him and reached Madrid. On 5th December, Moore left Salamanca to join forces with Baird, intending to threaten the French lines of communication. Two days later he was fortunate enough to capture enemy despatches containing the entire French order of battle, showing that Soult was dangerously isolated east of Leon with a force inferior to his own. Moore therefore decided to attack Soult immediately after he had effected a junction with Baird.

On 20th December, Moore reached Mayorga and there linked up with Baird's force advancing from Benavente. Hurriedly reorganizing his army into four infantry divisions (Baird, Hope, Fraser, and Paget), two light brigades (Alten and Craufurd) and one cavalry division (Lord Paget), he rapidly pushed on to Sahagun, which was captured in a cavalry skirmish on the evening of 21st December. Soult had withdrawn to Saldana behind the river Carrion and Moore planned to attack him during the night of 23rd December, hoping to seize the main river bridge intact under cover of darkness.

After the capture of Madrid, Napoleon had assumed that the British forces were falling back on Lisbon and had remained in the capital to reorganize his forces. It was not until 19th December that he learned that Moore's army was on the march towards the north-east and he then reacted with characteristic energy and speed. On 21st December he left Madrid at the head of his army and crossing the Guadarramas in appalling weather reached Villacastin two days later. Moore received news of the French movements on 23rd December and at once decided to abandon his intended attack and fall back on Astorga, where the mountainous country would provide some protection from the French cavalry. These orders reached the troops just as they were marching out to their battle positions and in deep dejection they returned to their bivouacs.

The following morning, Christmas Eve, 1808, the leading troops marched out on the road to Mayorga just as Napoleon's advance guard reached Arevalo some ninety miles to the south.

The great retreat had begun.

The Retreat

Phase I—Sahagun to Astorga

Some thirty-five miles behind Moore's position around Sahagun, the river Esla flows in a southerly direction. Although for the greater part of the year this river does not constitute a very serious obstacle, during periods of heavy rain it is subject to violent floods and, for this reason, the crossing of this river caused Moore considerable anxiety.

There were three possible crossing places—the bridge at Mansilla, south-east of Leon, the ford and ferry at Valencia de Don Juan and the bridge at Castro Gonzalo immediately east of Benevente. The most accessible, Mansilla, was held by the Spanish forces under de Romana, who, based on Leon, were about to co-operate in the attack on Soult. Moore therefore decided to leave this line of retreat to them, giving strict instructions that the bridge was to be destroyed. He suggested that, if Leon could not be held, they should retreat into the mountains towards Oviedo. The ford and ferry at Valencia could obviously not be used by his whole force, and he therefore directed the main body on to the bridge at Castro Gonzalo, whilst sending Baird's division to cross at Valencia. Covered by the cavalry and the two light brigades, the force moved back through Mayorga towards the Esla. Baird's division reached the river at Valencia on 26th December and, although hampered by rapidly rising flood water, the whole force succeeded in crossing by the same evening.

On the same day, the main body passed over the bridge at Castro Gonzalo, leaving Craufurd's light brigade holding the rising ground to the east to cover the demolition of the bridge, Craufurd himself being charged with the responsibility for its destruction.

SKETCH OF THE BRIDGE OVER THE RIVER ESLA. AT CASTRO. GONZALO. BY LIEUT. CHARLES BOOTHBY R.E. AFTER SUCCESSFULL DEMOLITION OF ONE PIER AND TWO ARCHES ON THE 29TH DECEMBER 1808

Napier gives us a vivid description of an attempt by a cavalry troop of the Imperial Guard to surprise one of the forward posts covering the bridge:—

"John Walton and Richard Jackson, privates of the 43rd, being posted beyond the bridge, were directed, on the approach of an enemy, the one to stand firm and the other to fire and then run back to the brow of the hill to give the alarm signal to the picquets. Jackson fired but was overtaken and received twelve or fourteen Sabre cuts in an instant. Nevertheless he came staggering on and gave the signal, whilst Walton with equal fortitude stood his ground and wounded several of his assailants, who then retired, leaving him unhurt. His cap, knapsack, belts and musket were cut in about twenty places and his bayonet bent double and notched like a saw."

The bridge was a massive masonry structure (see Boothby's sketch and photo 1) and Burgoyne, who was the senior sapper officer attached to Craufurd's brigade for this operation, recommended the destruction of one complete pier and two arches. Preparations for the demolition began on the morning of 27th December, troops from the covering force being used in shifts, some to cut through the arches selected for demolition and the remainder to hew a chamber for the main demolition charge in the intervening pier. The latter task must have involved the use of supporting timber, since Boothby mentions that: "the teeth of the cursed saws refused to do their duty and hours are spent sawing the woodwork".

By the evening of 28th December all was at last ready and in the darkness the covering troops withdrew and, passing over planks laid across the broken arches, reached the west bank without casualties. Finally soon after midnight the charge in the pier was fired "to good effect" and the covering troops withdrew to Benavente leaving a cavalry screen to harass the enemy.

Meanwhile Hope's and Fraser's divisions had linked up safely with Baird's at Astorga and Moore considered that his line of retreat was now secured. He had, however, reckoned without his Spanish allies. De Romana had decided to abandon Leon without a struggle and to direct his retreat, not upon Oviedo as expected, but upon Galicia by way of Astorga. On 30th December, his rearguard holding the Mansilla bridge was swept aside by Soult's Cavalry, leaving this vital bridge intact and by the following day Leon had fallen and Soult was poised for a flank attack on Moore's retreating army.

At this time, Moore had not yet decided whether to embark his forces at Vigo or Corunna and was awaiting a report from his C.R.E. (Fletcher) whom he had dispatched to Corunna to carry out a reconnaissance. He therefore determined to secure an alternative line of retreat by dispatching his two light brigades under Craufurd to seize the important bridge over the river Minho at Orense with orders to proceed thence to Vigo for embarkation. These brigades therefore left the main body at La Baneza and took no further part in the subsequent campaign.

About this time Moore received a report from another sapper officer (Captain Carmichael Smith), who had been sent to examine possible defensive positions on the route between Astorga and Lugo. He recommended only one position, that at Cacabelos—some five miles east of Villafranca, where the river Cua crosses the main highway. Therefore in view of the immediate threat of a flank attack from the direction of Leon, Moore determined to execute a rapid withdrawal to the Cacabelos position.

The position at Astorga itself had deteriorated into chaos and confusion. De Romana's starving militiamen filled the town and the destruction of the whole of Baird's heavy equipment and stores, which could not be moved back due to lack of transport, gave an opportunity for wholesale plunder and looting. Nonetheless by the evening of 31st December, Moore's rearguard was marching westwards out of the town, whilst de Romana's force followed a hill track into the mountains, where they would be safe from the French cavalry. On the following evening (1st January) the French forces under Soult and Ney converged upon the town so recently evacuated—Moore had only extricated his army in the nick of time.

Phase II—Astorga to Lugo

At this stage, it is interesting to compare the strengths of the forces engaged during the remainder of the campaign. Excluding the two light brigades, the strength of Moore's army at the beginning of the retreat was approximately 22,000, whilst that of the two French corps involved (Soult's and Ney's) must have been about 30,000 and 16,000 respectively, giving the French a superiority of about two to one.

Westwards from Astorga the road passes through mountainous country with many steep gradients and narrow sections. The weather was appalling with snow falling upon the icy surface of the highway, which in places was deeply rutted. In these circumstances it is little wonder that control broke down and discipline was relaxed. At Bembibre, which was evacuated by the rearguard on 2nd January, the wine cellars had been broken open and drunken troops were left lying around the streets to be massacred by the French cavalry.

Passing through Ponferrada, the rear guard took up their positions behind the river Cua at Cacabelos on 3rd January. In spite of the natural strength of this position, Moore realized that it would be impossible to maintain his whole army for long in this barren country and decided to send the main body straight on to Lugo. No attempt was made to destroy the bridge over the Cua as the river was shallow and easily fordable and as a result the French cavalry were able to charge straight through into the main rearguard position. Here, however, they met a murderous crossfire from the troops concealed in the vineyards on either side of the road and were forced to withdraw after suffering heavy losses. Tom Plunket, a noted marksman of the 95th brought off a long shot, "bagging" Colbert the handsome young cavalry brigadier at extreme range. During the night the rearguard withdrew and the retreat continued in appalling weather through the mountain passes west of Villafranca. At Constantino (see Photo 2), the engineers failed to destroy the central arch of the bridge, which it had been intended to demolish and a little further on at Nogales, which was evacuated by the rearguard on 5th January, there was a similar occurrence "for want of a sufficiency of tools". On 6th January, the rearguard entered Lugo, at which place the force was joined by Leith's brigade, which had been guarding Baird's communications with Corunna.

During this phase, the troops had been forced to march extreme distances under appalling weather conditions and there were numerous casualties especially among the women and children who accompanied the force. It was Moore's intention to give battle at Lugo, since the highest of the mountains were now passed and his communications with Corunna secure; he therefore deployed his force in a strong position just east of the town and waited for the enemy to come up.

Phase III—Lugo to Corunna

On 7th January Soult's advance guard attacked the Lugo position and was easily repulsed. The following day he showed no inclination to renew the attack and Moore realized that the wily old Marshal intended to build up his force to full strength before risking a general engagement, he therefore reluctantly gave the order for a withdrawal during the night 8th/9th January. By this time the army had recovered much of its former discipline and spirit and it was confidently expected that the remainder of the retreat would be conducted without substantial loss. Fate however willed otherwise. Just as the troops were beginning their withdrawal a violent storm occurred. Guides were lost and marks obliterated. Many brigades wandered all night on the slopes around Lugo, when they should have been well on their way to Corunna. Once again discipline broke down and many troops strayed from the ranks especially in Baird's division.

Two important bridges, the first over the river Minho, at Otoro del Rey (see Photo 3) west of Lugo and the second over the river Ladra (see Photo 4), halfway between Lugo and Betanzos, were not destroyed "due to wet powder and unskilful handiwork". Napier speaks of "several bridges between Lugo and Betanzos, which the Commander-in-Chief had ordered to be destroyed —but the engineers failed of success in every effort".

By the evening of 10th January, the rearguard had reached Betanzos, set among sunny orange groves near the coast and took up a position to cover the demolition of the substantial timber bridge over the river Mandeo, just outside the town. On 11th January an attack by French cavalry was repulsed by the covering troops, and the demolition fired, but the bridge was only slightly damaged "due to a partial failure of the mines". It is related that, when the news of this was brought to Moore, he turned to Fletcher with the words "What! another abortion! And, pray Sir, how do you account for this failure?"

The short distance to Corunna was quickly covered, being reached by the main body on the same day. Bryant relates how the Guards entered the town in perfect formation "with drums beating and the drum major twirling his staff".

On 12th January, the rearguard crossed the river Mero, at Burgo a few miles south-east of Corunna, the bridge being successfully destroyed. Another bridge some five miles further up the river at Cambria was also destroyed. The engineer officer at the latter bridge "mortified at his former failures, was so anxious to perform his duties in an effectual manner that he remained too near the mine and was killed by the explosion". Unhappily even these successes were not wholly effective, since a third bridge at Celas "some two leagues higher up the river" remained intact and was crossed by the French cavalry next day.

By 13th January, the whole of Moore's force was concentrated in and around Corunna, having covered 265 miles in some twenty days over mountainous country in appalling weather.

That same day, a powder magazine outside the town containing 4,000 barrels of powder was destroyed. The effect of this was reminiscent of a nuclear explosion: "there ensued a crash like the bursting forth of a volcano, the earth trembled for miles, the rocks were torn from their bases, the agitated waters rolled the vessels as in a storm, whilst a vast column of smoke and dust, shooting out fiery sparks from its sides, arose perpendicularly and slowly to a great height".

Thus ended the retreat, in which Moore's army lost some 5,000 men, the greater part of whom had fallen by the way through fatigue and sickness rather than by enemy action. Ill discipline and drunkenness there undoubtedly were in a marked degree, but there were also many shining examples of self sacrifice, heroism and courage. Above all, whenever the British forces stood at bay, they invariably proved themselves superior both in skill and steadiness in battle to their seasoned and experienced opponents.

The Battle of Corunna

On reaching Corunna on 11th January, Moore had been mortified to find that no shipping awaited him and it was only on 14th January that the transports from Vigo finally put into harbour. On board one of the escorts, the Barfleur, was young Boothby, who having reconnoitred the route to Vigo, had taken the first opportunity of rejoining the main force.

The following day, appreciating that the ground did not favour the use of cavalry and that he could only deploy a limited number of guns, Moore ordered the cavalry and the bulk of the artillery to embark. The horses were therefore destroyed and the men went on board, reluctant to turn their backs upon the French.

The disposition of Moore's force is clearly shown on the accompanying plan of the battle. Having insufficient forces to hold the ring of high ground overlooking Corunna, he decided to hold the subsidiary ridge connecting the two key villages of Piedralonga and Elvina with a portion of his force echeloned back to the west. Thus deployed he awaited the enemy attack.

However by mid-day on 16th January, no attack had developed, and Moore decided to put into operation his plan for the withdrawal and embarkation of his forces. Fraser's reserve division were ordered to move down to the harbour and the remainder of the army was to follow as darkness fell. Suddenly at about 1400 hrs., the French were seen swarming down from the heights of Penasquedo and the heavy battery, which Soult had laboriously erected opposite the village of Elvina, opened fire. Boothby gives a graphic description of this moment:—

"At one o'clock I was charged with the erection of a battery in the town and some other works on the ramparts. Soon afterwards, we heard firing begin—sharpshooting at first and then more general—and so much cannonade, as convinced me it must be more serious than on the preceding day. Nothing I could say or do could prevail upon the soldiers to lay aside the air of the last extremity of fatigue, which they had assumed. The shovel of earth approached the top of the bank as leisurely as the finger of a clock marches round the dial. I was therefore a good deal struck with admiration at their behaviour when at four o'clock an order came for them to rejoin their regiments, which were marching to the field. They threw down their tools, jumped to their arms, hallooed and frisked as boys do, when loosed from school—these poor tattered half dead-looking devils".

Soult's plan, which had been largely foreseen by Moore, was to capture the village of Elvina, turn the British right, and then to crush the left and centre by a frontal assault. The impetus of the French assault carried them into the village of Elvina, which was only given up after hard fighting. Moore then ordered up Paget's division from its position around Oza and personally organized a counter attack, which caught the French off balance and pushed them out of the village. Our counter attacking troops in turn came up against the French reserves and were driven back in some disorder. Elvina fell into French hands once again. There was still no sign of Paget's division and Moore decided to commit his last immediate reserve—Warde's Guards brigade. At this critical juncture, Moore was struck down by a cannon ball, which inflicted a grievous wound in his left side, and was carried from the field, the command being assumed by Hope, since Baird had earlier become a casualty. The Guards' counter attack proved successful and shortly afterwards Paget's division forced back the French column, attempting to push round the British position and advanced rapidly to menace the French left flank.

At about this time Soult launched Merle's and Delaborde's divisions upon the British centre and left, but after heavy fighting they were thrown back in disorder. By 1700 hrs. as the winter sun sank behind the hills, the whole French army was falling back in disorder. Had Moore remained on the field, he would undoubtedly have exploited this promising situation, but the cautious Hope was unwilling to commit his forces any further and decided to withdraw and embark the army. On this occasion, the staff work was excellent and by first light on 17th January, the whole force had safely embarked with the exception of two brigades which remained ashore to cover the embarkation of the wounded.

During 17th January, the French succeeded in mounting two guns, covering the harbour and these caused some confusion to the shipping, but little serious damage was done. By the afternoon the wounded were all aboard and the reserve brigades began to embark. As darkness fell the last British troops went on board and the fleet cleared the harbour during the night.

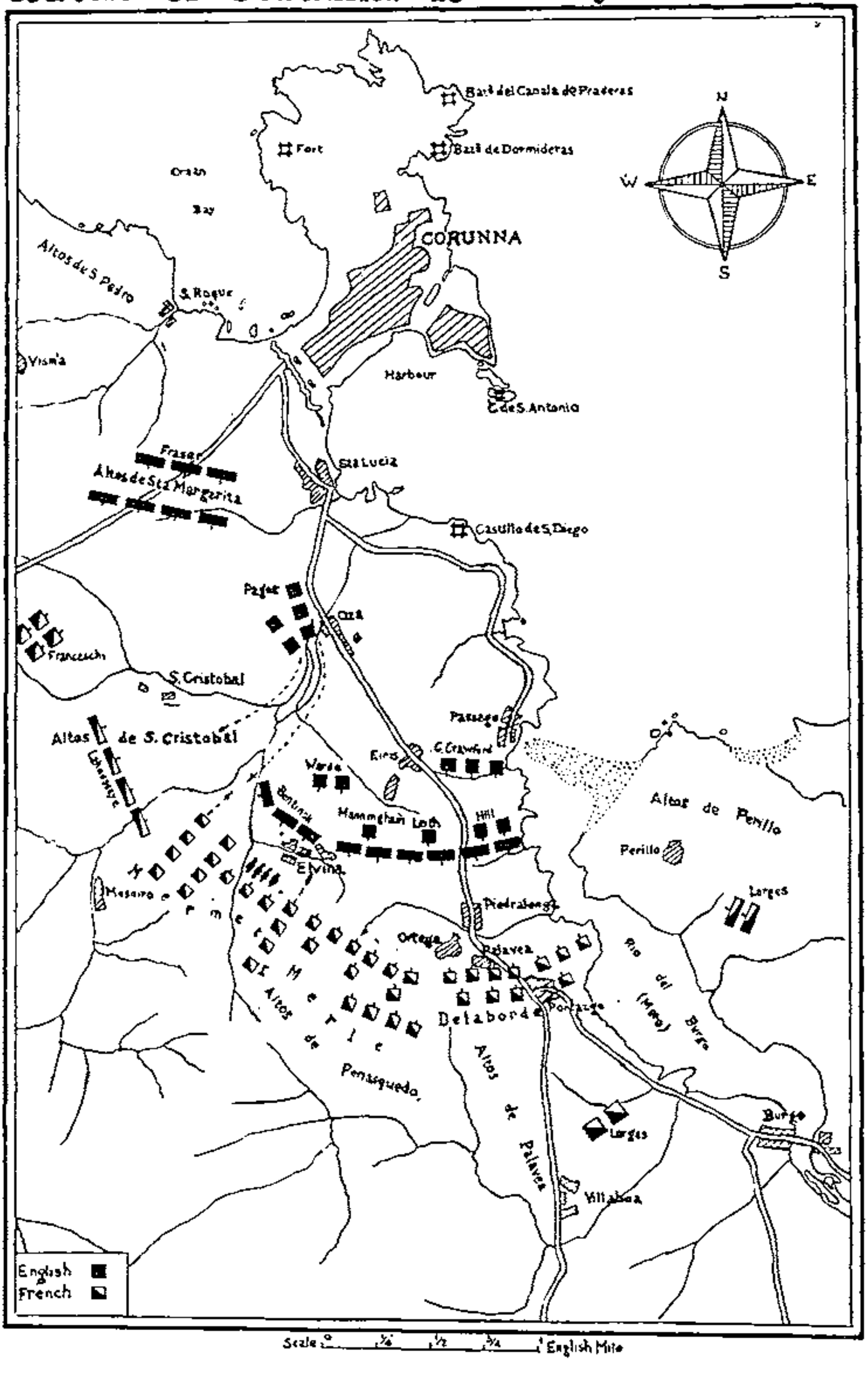
Thus ended the battle of Corunna—a wonderful example of the skill, tenacity and endurance of the British soldier. Boothby's "tattered devils" had no regard at all for their French adversaries. They could not conceive of being beaten by them. So they won and won handsomely. For many, however, including Boothby, this victory was marred by the death of "the man, whom I looked up to as a god and held in the most cordial respect and affection". Moore had died on the night of the battle and was buried the following morning on the landward bastion of the citadel. Undoubtedly he had pushed his army beyond the normal limits of human endurance and had often failed to use the many opportunities of delaying the enemy, which the nature of the country afforded. Yet he had extricated his army from a position of extreme peril and in spite of ill-discipline and appalling weather had brought out safely more than four-fifths of his force. "Faults he committed and who in war has not? Yet shall his reputation stand upon a sure foundation—a simple majestic structure, which malice and envy cannot undermine."

The Work of the Engineers During the Retreat

Moore's demolition policy

Since it is upon their alleged failure to demolish the bridges on the line of the retreat, that the criticism of the engineers is wholly directed, it is important to appreciate the policy of the Commander in Chief in this respect. He realized that the pursuing French forces would be lightly equipped with only essential field artillery and wheeled vehicles. He knew that the rivers were in the main easily fordable and that on the other hand the bridges were massive masonry structures requiring much time and effort to prepare for demolition. Moore also had a high opinion of the professional ability of the French engineers. He therefore considered that demolitions should be limited to those sites where genuine obstacles could be created. His views may to some extent have been coloured by the events at the Esla crossing at Castro Gonzalo, where a successful demolition taking two full days to prepare was surmounted by the French engineers in under twenty-four hours. It is interesting to note

Battle of Corunna. 16 January 1809.



that Napoleon viewed the destruction of bridges as "barbaric" and even Moore himself felt that wherever possible the people of Spain should be spared the destruction of "this priceless heritage".

Moore's policy is clearly brought out in the first published narrative of the campaign written by his brother James Moore in 1809:—

"There were some officers who criticized the operations that were adopted, and the subject of blowing up bridges was one of these upon which they chiefly dealt. General Paget at length mentioned this to Sir John Moore and pressed him to destroy more. In reply, Sir John bade him look around and examine the nature of the rivers over which the bridges were thrown. He pointed out to him that both infantry and cavalry could usually pass a little above or below these bridges and that the obstruction to artillery could quickly be repaired by an army constituted like the French."

Results

Let us now examine the results achieved. There is no complete record of the bridge demolitions attempted, but the following summarizes information taken from a number of reliable sources and is given in chronological order:—

	Site	*River*	*Construction*	*Result*
1.	Castro Gonzalo	Esla	Masonry	Successful
2.	Constantino	Navia	Masonry	Failed
3.	Nogales	Navia	Masonry	Failed
4.	Otoro del Rey	Minho	Masonry	Failed
5.	Bahamonde	Ladra	Masonry	Failed
6.	Betanzos	Mandeo	Timber	Partial failure
7.	Burgo	Mero	Masonry	Successful
8.	Cambria	Mero	Masonry	Successful

To summarize, eight demolitions were definitely attempted, of which only three were successful.

Possible Causes of Failure

In this article, the remarks of certain historians, who have described these events, have been recorded in their respective contexts, but these are almost certainly based on current rumour and a more logical approach to the problem is therefore necessary.

(a) Reconnaissance

This appears to have been well carried out in ample time. During his initial advance Baird wrote to Moore on 21st November: "I have also despatched engineer officers for the purpose of ascertaining what impediments to the progress of the enemy we might occasion by the destruction of bridges, etc., in the event of being hard pressed and compelled to fall back on Galicia". There can therefore be little doubt that the reports of these officers reached the Commander in Chief before the retreat began.

(b) Manpower

An examination of the order of battle shows that although an adequate number of engineer officers were attached to the force, there were no military artificers and therefore all work was presumably carried out by the infantry under the supervision of the engineer officers. The men of Craufurd's brigade were certainly employed on the demolition of the Esla bridge

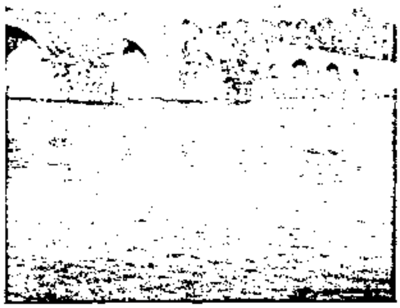


Photo 1—Bridge over River Esla at Castro Gonzalo.

Photo 2.—Bridge at Constantino.

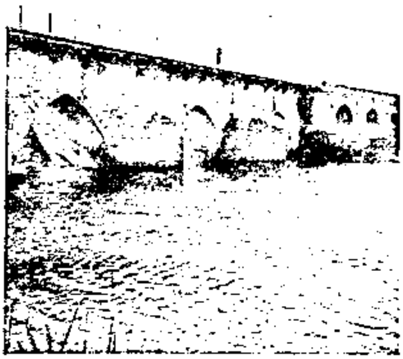


Photo 3.—Bridge at Otero del Rey.

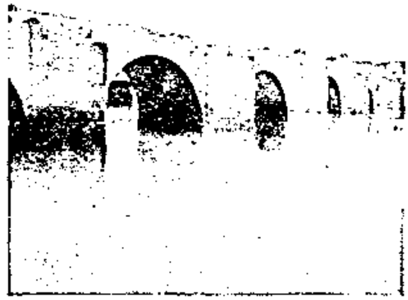


Photo 4.—Bridge over River Ladra near Bahamonde.

and the incident quoted from Boothby's diary at Corunna shows him to have been in command of an infantry working party at the time. It had not yet been appreciated that engineer work in the field required not only skilled planning and supervision but skilled execution also. The lack of skilled labour must therefore be rated high amongst the possible causes of failure.

(*c*) *Tools*

When no military artificers were attached to a force, all tools were carried with the divisional baggage and appear to have been accorded no special priority. Lieut.-Colonel John T. Jones, R.E. whose history has already been briefly referred to, writes that: "during the retreat, the bridges could not be destroyed for want of implements" and later, when discussing the successful demolition of the Mero bridge at Burgo: "the engineers had been able to obtain from Corunna the necessary tools to accomplish the destruction of the bridge".

Jones' views receive remarkable confirmation from a letter written by a Colonel T. Sorell soon after his return to England from this campaign: "the order given by Sir John Moore to destroy the entrenching tools at Astorga

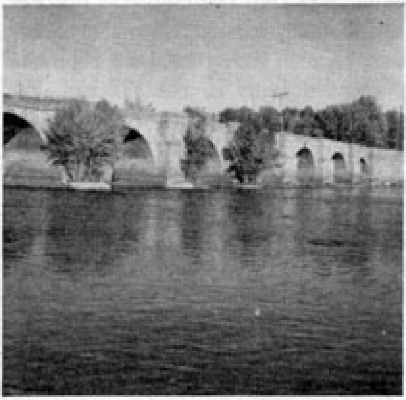


Photo 1—Bridge over River Esla at Castro Gonzalo.

Photo 2.—Bridge at Constantino.

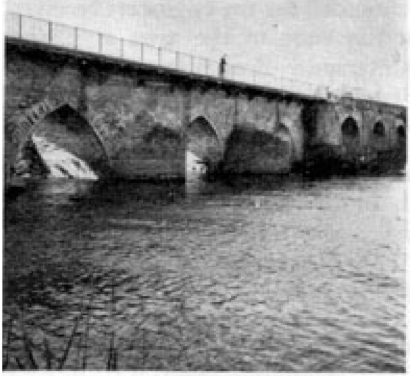


Photo 3.—Bridge at Otero del Rey.

Photo 4.—Bridge over River Ladra near Bahamonde.

The Great Retreat 1 , 2 , 3 , 4

was interpreted too literally. The consequence was that the engineer officers, who were employed to mine the bridges could not procure the instruments, which were necessary to form the mines properly and they therefore exploded partially without producing effect. This was no fault in the officers, but arose, I believe, from the cause, I have mentioned". It appears then that the tools were for the most part destroyed at Astorga and that in consequence sufficient were not available, until the supplies at the Corunna base could be brought forward. This would account for the fact that, whereas the Esla bridge, east of Astorga, and the Mero bridges, close to Corunna, were successfully destroyed, those on the section of the route between Astorga and Betanzos were left substantially intact.

(d) Explosives

It has been alleged by some historians that wet powder accounted for some or all of the failures. This view does not, however, find general support and it is interesting to note that no similar complaint was made with regard to the charges used by the artillery, although guns were in action several times during the retreat. It may, however, well have been that the artillery safeguarded their own supplies, whilst those intended for the engineers received less attention. Boothby's remarks about the state of the saws at Castro Gonzalo shows that the standard of maintenance of engineer tools left a great deal to be desired, and the powder may have been similarly neglected.

Deductions

The poor results achieved undoubtedly justified criticism, but this criticism was for the most part thoroughly ill informed. The Commander in Chief laid down a sound demolition policy, based on early engineer intelligence. The demolitions were selected with due regard to the resources available, and, if properly executed, would have provided a serious obstacle to the French pursuit.

The poor execution was undoubtedly attributable to two main factors—the absence of skilled military labour and the lack of proper tools.

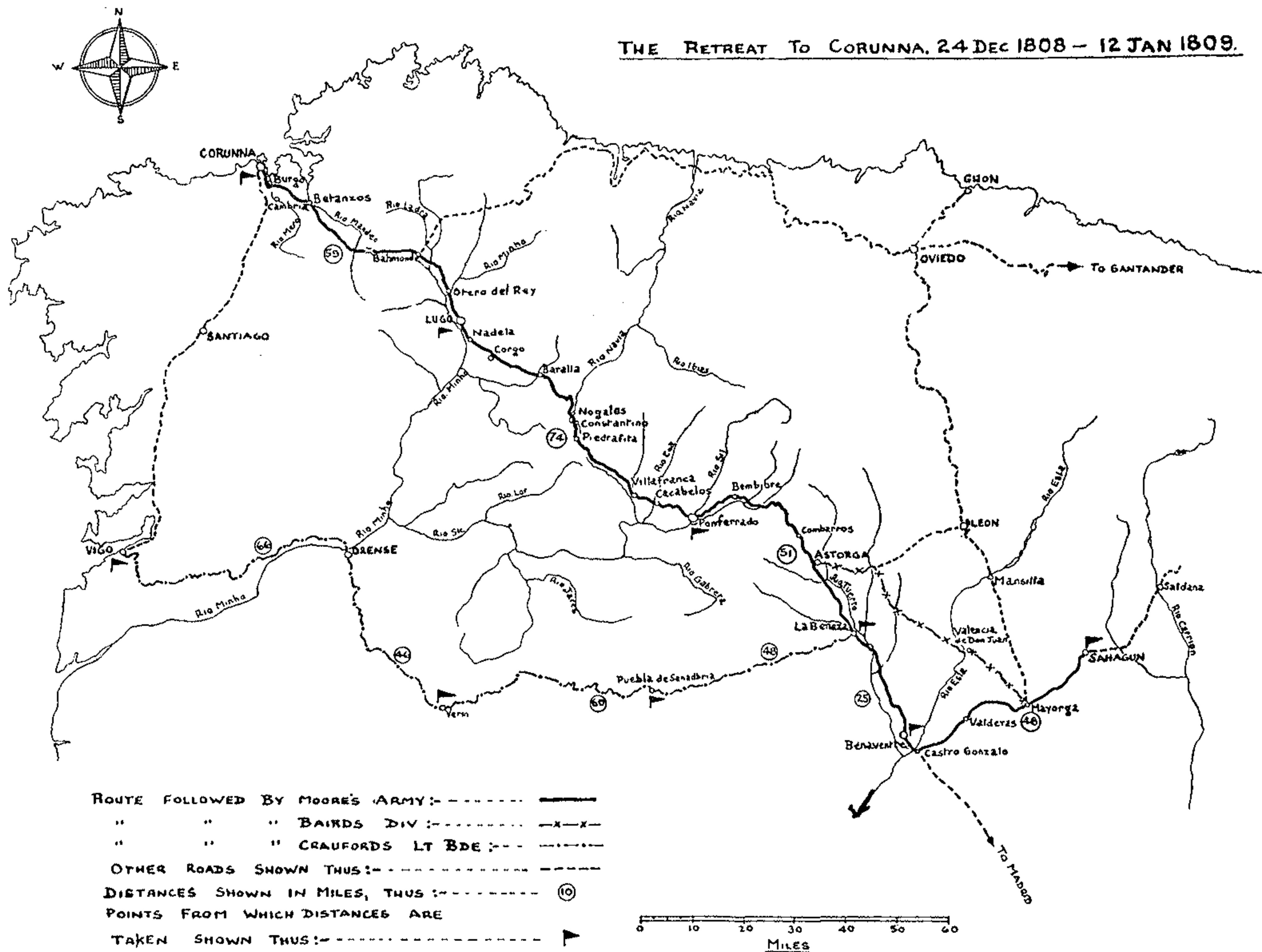
This campaign should have made apparent the important lesson that, in the field, engineer work can only be satisfactorily achieved by skilled, experienced and well trained men suitably equipped and organized. It is sad to reflect that it took another fifty years before this lesson was fully learned and the Corps of Royal Engineers in its present form came into being.

Conclusion

This article has, I trust, clearly shown that the handful of engineer officers in Moore's force fully maintained the high traditions of our Corps in the face of appalling difficulties. To them, equally with the other arms of the army, can be applied those famous words of Napier:—

"The exploits of this army were great in themselves—great in their consequences—abounding with signal examples of high courage and devoted zeal. They should neither be disfigured nor forgotten, being worthy of more fame than the world has yet accorded them—worthy also of a better historian".

The Retreat to Corunna, 24 Dec 1808 – 12 Jan 1809.



Erection of Totem Pole in Windsor Great Park

By Lieut.-Colonel K. L. Taggart, R.E.

Introduction

The Canadian province of British Columbia is 100 years old this year, and as part of the centenary year celebrations a Totem Pole was presented to Her Majesty the Queen and had to be erected in Windsor Great Park. The Ministry of Works were responsible for the project as a whole, but because of the Corps association with British Columbia (already described in previous issues) it was decided that the preparation of the foundations and the actual erection of the pole should be done by men of the Royal Engineers.

It was towards the end of April that the Commanding Officer 22nd Field Engineer Regiment was asked whether he could do this job and what help he would require. It was to be considered partly as an operational task and partly as training. At that time the only information available was that the pole was 100 ft. long (1 ft. for every year) 4 ft. 6 in. diameter at the butt and weighed 14 tons. It was decided that 3rd Field Squadron would erect the pole and that they would require two mobile cranes (each with 70 to 80-ft. jib and a lift of 15 to 20 tons) and further details about the pole.

The task was accepted on 28th April and the pole had to be up by mid June. If the concrete in the foundation was to be up to full strength by then it had to be poured by mid-May—20th May was in fact set as a completion date. It should be pointed out that one of the troops was away in Portsmouth on a demonstration and the squadron strength was therefore down to twenty working numbers.

Site Reconnaissance and Preparation for Work

It had already been decided that the totem pole should stand near Wick Pond in Windsor Great Park at the end of an avenue of Canadian trees and that the carved figures on the pole should face up the line of this avenue. A detailed reconnaissance of the site was carried out on 30th April. Levels were taken at the important sections and the centre point of the foundation was fixed as far from the lake as possible. The ground sloped sharply down to the lake and this was to have quite a large effect on the plan for erection.

The reinforced concrete foundation had already been designed in Canada but the size of the footing slab was to be decided when actual soil conditions were known. Reconnaissance showed that the soil was generally a sandy gravel on top with gravelly clay underneath. The safe bearing pressure was estimated to be 1 ton per sq. ft. and the footing was designed on this.

Construction of Foundation

The foundation was designed like an outsize candlestick with a reinforced concrete annulus (4 ft. 9 in. diameter internally, 5 ft. 9 in. deep and 10 in. thick) on a square reinforced concrete footing. The vertical reinforcement of the annulus was bound in two concentric rings with anchorages in the footing and supported the coping reinforcement at the top. A bronze pin (4 in. in diameter) to help in positioning the pole as it was being lowered was set centrally in the footing. Normal Portland Cement was to be used in the concrete and the mix proportions were to be designed after analysis of the aggregate. As it happened this worked out very conveniently at 1:2:3.

After a quick assessment of the stores and equipment required, the job of collecting them began. As time was short all demands went direct to S.O.R.E. Stores Eastern Command and those stores not collected by the squadron were either delivered to the site or to the Garrison Engineer in Windsor who kept the account for the project and helped in many other ways. Some of the stores were not readily available and the squadron transport covered many miles of southern England before they were all collected.

As soon as the reinforcing bar was received it was cut and bent to shape with the help of 6 Field Park Squadron Workshops, and the two major components were made up there. The timber and metal formwork was also prefabricated in the workshops. The central formwork consisted of two circular sections of sheet steel each in three segments, interlocking, and rolled to shape in the G.W.R. Works in Swindon. They were to be held in position by wedges so that the whole could be easily dismantled.

On 10th May, 1 Troop moved to Farnborough and began excavation for the foundations. The main excavation was 14 ft sq. and 8 ft. 6 in. deep. A ramp from the existing path was also dug to assist in moving and placing the wet concrete. Seepage water was met when the hole was 6 ft. 6 in., but pumping kept it reasonably dry until the full depth was reached. A sump was then dug and emptied regularly.

Concreting began on 15th May when a first layer was poured 6 in. thick to provide a good working surface and platform for the reinforcement and to refresh ourselves in concreting techniques. When this first layer of concrete had set the two main rings were lowered into place and the bottom footing reinforcement was fixed to them. The bronze pin which was to be taken as a datum point was drilled in two directions at right-angles so that it could be fixed in relation to the rings by two straight lengths of $\frac{3}{8}$-in. reinforcing bar. When the layout of the reinforcement had been checked the footing was poured in two 18-in. layers up to the bottom of the hole for the butt—a total thickness of 3 ft. 6 in. Tamping was carried out using 4 in. by 3 in. beams across the work and, where necessary, by mechanical vibrator. Minor adjustments were then made to the vertical bars and the coping reinforcement was added at the top. It was whilst this was going on that the detachment was honoured by an informal visit from Her Majesty The Queen who talked with the Squadron Commander and showed great interest in what was going on. The fitting and exact location of the central formwork for the annulus was quite difficult but was finally achieved to within $\frac{1}{8}$ in. The annulus was then poured in one operation, the outer formwork being built up in stages from ready-made boards so that the concrete had not to drop any great height. The mechanical vibrator was particularly useful here to ensure even packing round the closely spaced annulus reinforcement. Fortunately throughout this period the weather was good and there was only an occasional shower of rain.

Initial Plan for Erection

Quite early in May it was apparent that we would not get the cranes we wanted and as the pole was already on the high seas it was unlikely we would have any more details of its dimensions. The initial plan was therefore made on the assumption that cranes would not be available and the pole would have to be erected by "stick and string" methods. The design for lifting attachments would have to be based on estimates of dimensions from photographs. A plan to use a gantry made up of Bailey bridge components was considered but was rejected when a rough design showed that far too many stores would be needed. A suggestion from the Engineer-in-Chief's office that Transportation Derricks could be used was followed up and, as they seemed the best means of lifting we could hope for, the plan was based on using them.

There were two main problems to solve. Firstly, the design of the foundation was such that the pole had to be lifted completely before inserting it in the hole—sliding it in would damage either the coping or the timber. Secondly some form of clamp, to which lifting blocks could be fitted, had to be designed to fit tightly enough around the complicated carving of the pole to lift its weight and yet not damage it. A minor problem was that the pole had to face in a particular direction.

The initial plan was to lift the pole just above its point of balance with two derricks one on either side of the hole, skidding the butt on greased chesses until it was vertical over the hole. It would then be lowered into the hole centring itself on the bronze pin. The pole would have to be positioned before lifting so that it lay with its point of balance between the derricks with its face upwards and the butt on the higher ground.

Having decided this, the remainder of the plan was largely a matter of solid geometry and of following the instruction handbook for the derricks. There were several difficulties which affected the geometrical layout:—

(*a*) We had asked for two heavy derricks each of 15 tons lift at a radius of 12 ft. However, the components for a second heavy derrick could only be got together with great difficulty and it was agreed that the second derrick would be a light derrick with a lift of 6 tons at a radius of 8 ft. This meant that although the layout was designed symmetrically, as far as possible, it might be difficult to keep equal loads on the derricks and in the final lift either the loads would be unequal or the light derrick would be overloaded.

(*b*) The derricks were only 70 ft. high—this meant first that the pole would foul the derrick guys as it went up and some guys would therefore have to be duplicated, and secondly that allowing for chock a block and lifting attachments the maximum height of lift was barely 55 ft. Not having precise information about the pole we could not be sure where the point of balance would be but it was obviously going to be fairly tight.

(*c*) The derricks had to be sited so that they were wide enough apart to allow the pole on its transporter to be driven between them but not so wide that the derricks' load capacity was too much reduced.

(*d*) Because the ground near the lake was fairly soft and some 6 ft. below the ground level at the foundation the winches had to be set to one side with their ropes crossing close to the hole.

(*e*) The two derricks were to be erected close to each other and guys would have to be moved to avoid interference between them.

The layout of each derrick was as near as possible to that shown in the instruction book but each had to be modified slightly to overcome the difficulties mentioned above and to suit the site. Where possible existing trees would be used as anchorages. Four guys would be fitted to the pole 25 ft. from the top. Three of these would clear all the derrick guys as it was lifted. The fourth was brought down to a shackle at the lifting point so that it came under the derrick guys and could be used early on as an additional safeguard against the pole falling. Four foot-ropes were fitted to the butt to control it

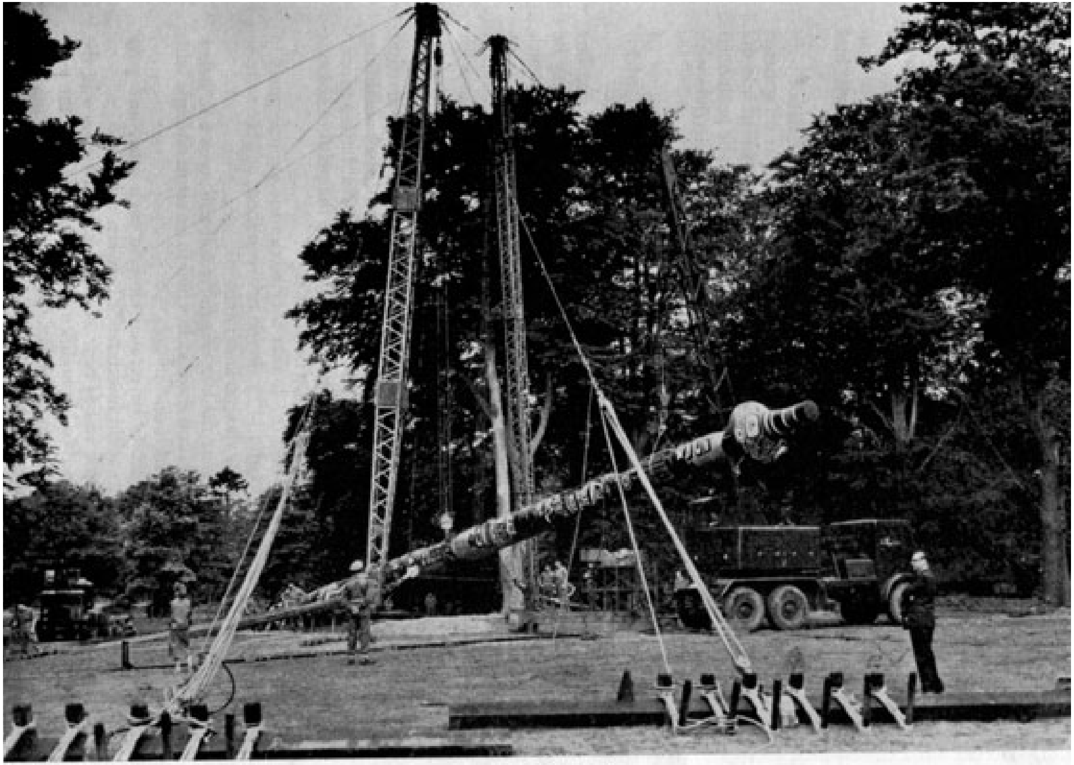


Photo 1.—Lifting begins.

Erection of Totem Pole In Windsor Great Park 1

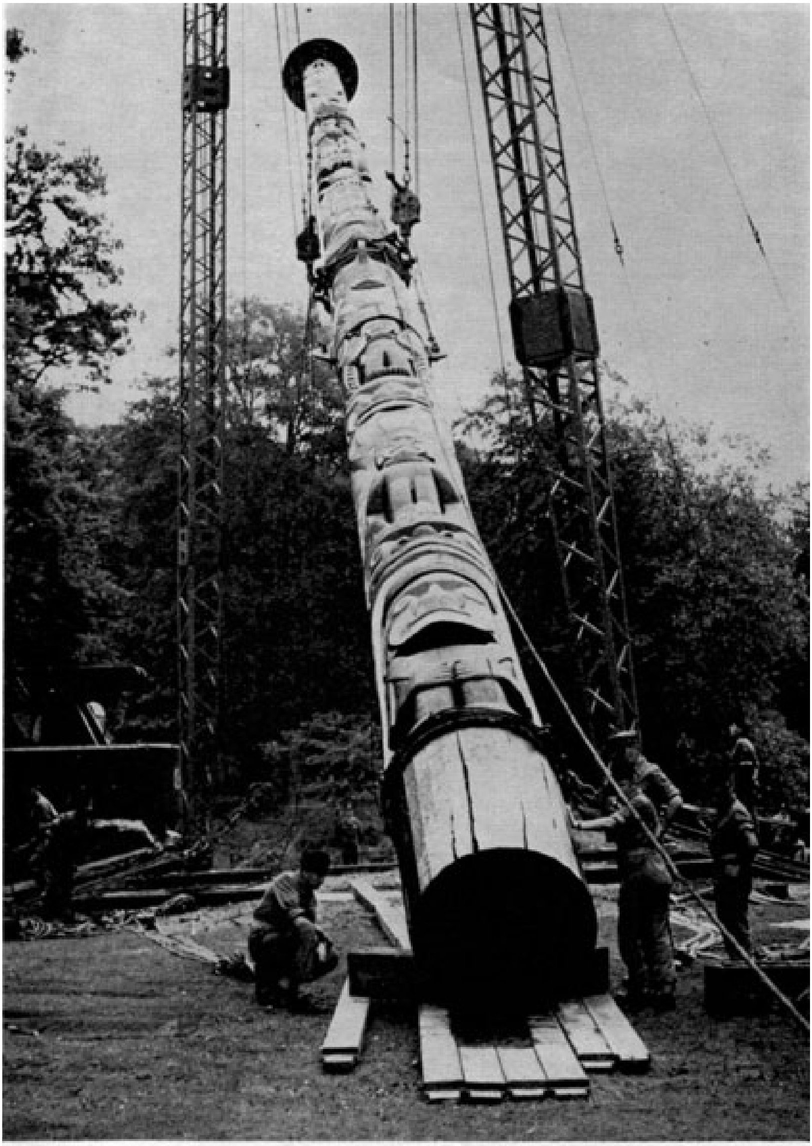


Photo 2.—Belt and braces.

Erection of Totem Pole In Windsor Great Park 2

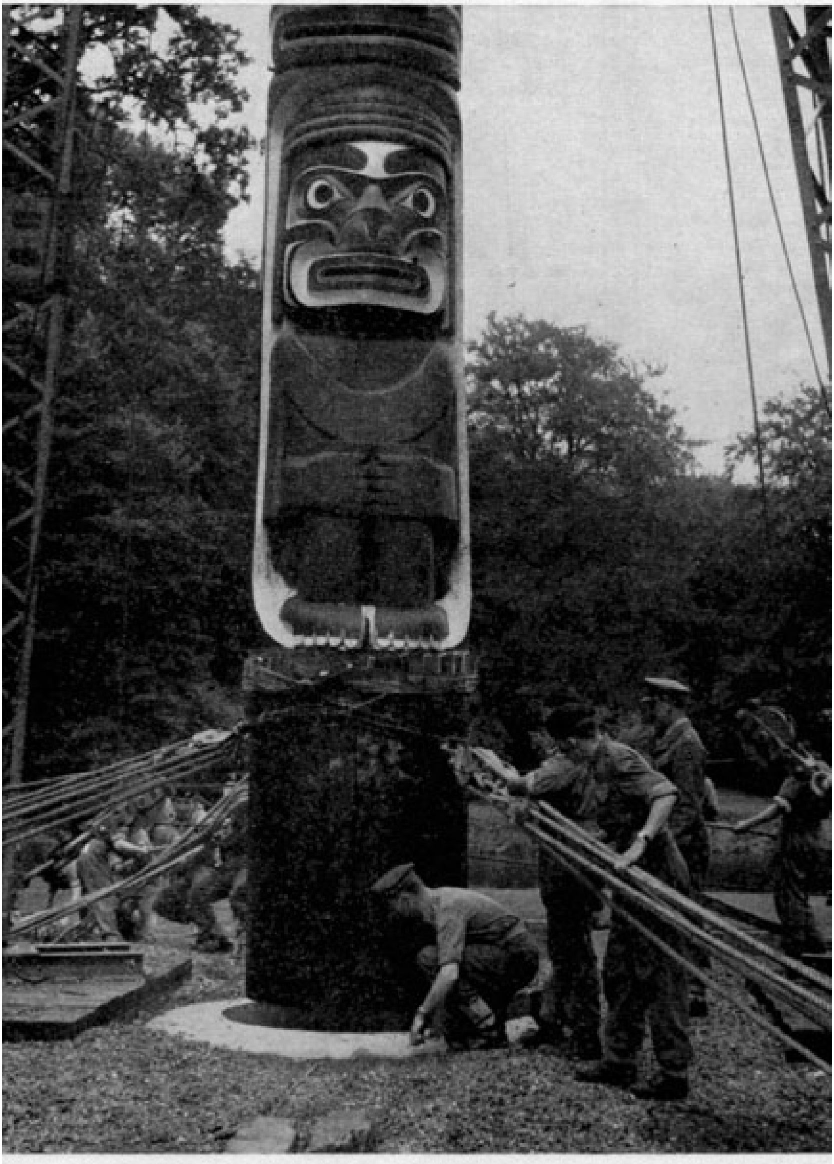


Photo 3.—Ready for lowering.

Erection of Totem Pole In Windsor Great Park 3

while sliding and to centralize it over the hole when the pole was vertical. Several anchorages were made for them so that they could be moved as the pole was lifted.

From photographs it was estimated that the pole was 1 ft. 6 in. diameter at its top and a collar was designed to fit a diameter of 3 ft. 7½ in., that is at the point of balance, allowance being made for packing round the pole. The collar consisted of two semi-circular sections of ¼ in. steel plate 18 in. deep with wide flanges. The flanges were drilled so that they could be bolted tightly to each other and with a larger hole in each side to take the shackle of the lifting gear. The packing would consist of timber, coir matting and hessian.

The plan depended on the pole being strong enough to avoid breaking under its own weight when being lifted. The timber was understood to be Group IV and calculation showed it should be strong enough with a fair margin of safety. As an additional safeguard it was planned to lift the pole at first by its tip as far as the Coles Crane could manage.

Practice in Erection of Derricks

To make sure that there were no further difficulties the opportunity was taken to practice erecting the derricks on the Regimental Training Area at Chiseldon. Except for the use of tree anchorages the derricks were erected as they would be at Wick Pond.

With the help of a warrant officer instructor from Transportation Training Centre the derricks were put up without great difficulty although several important lessons were learnt. As a result of this practice minor modifications to the plan were made.

Final Plan

The dimensions of the pole were not known until it was measured on board ship in Surrey Commercial Docks on 20th June. It was soon appreciated that the collar we had made was too big and instructions were given to alter it. However, we were lucky enough to find a place where the pole could be lifted without a great deal of packing or preparation. At this point the cross-section had been reduced to form a nose but it was reasonably high up (about 50 ft.) and calculation showed it ought not to break when lifted there. It was therefore decided to take the main lift at this point but to fasten the altered collar some 10 ft. below it and connect the lifting blocks to the collar by S.W.R. stirrups—we were literally going to use belt and braces!

Preparation for Erection

Erection of the derricks in Windsor Great Park had already begun on 17th June and went reasonably smoothly except that several trees had to be trimmed to avoid fouling the derricks while they were being lifted. Once completed they were again tested under load and no weaknesses were found. The date of erection had been fixed for Wednesday, 25th June, provided the civilian haulage contractors could deliver the pole to the site by the Monday morning. The pole arrived on time and was moved into place on its transporter without difficulty. It was unloaded one end at a time using the Coles crane. Once on the ground it came on charge of the regiment and Messrs. John Silberman Ltd. received a signature for "1 Totum (*sic*) Pole as loaded at Surrey docks."

The following work had then to be done to prepare the pole for lifting:

(*a*) The collar was attached and bolted tightly.

(*b*) Each lifting block was shackled to a S.W.R. strop which had been fastened under the nose in a clove hitch. The two blocks were connected under the pole by a third strop to stop them shifting during the initial lift.

(*c*) The collars and blocks were connected by two S.W.R. stirrups.

(*d*) A 1-in. notch was cut in the butt 5 ft. 9 in. from the bottom to take the waterproofing seal—fungus and rotten bark were removed from the butt and several coats of bituminous paint were applied.

(*e*) Guys for adjustment and holding were fitted 25 ft. from the pole top and foot-ropes were attached to the butt.

(*f*) The "top hat" arrived in a separate packing case and had to be fastened to the top of the pole with 4-ft. stainless steel bolts. It was found that the nuts provided did not fit these bolts and they had to be hurriedly rethreaded in REME Command Workshops in Aldershot.

On Tuesday evening everything was ready for lifting.

Erection of the Pole

On Wednesday morning at nine o'clock the slack in the derrick lifting tackles was taken up on the winches and the pole was lifted at its tip by the Coles Crane. Then by taking in on the winches one at a time (taking in on both winches together caused the pole to vibrate) the slack was again taken up and the crane lifted a little more. This process continued up to the crane's limit of lift. Winching went on slowly stopping only for one break and when the derrick guys had to be slackened and transferred as the pole reached them. The greased chesses were very effective in keeping the butt moving towards the hole.

All went well except that one of the blocks began to bite into the pole and made it hang slightly out of plumb. It could not be cleared but this was not very serious and the pole was eventually upright over the hole soon after three o'clock. Some heaving on the foot-ropes was necessary to centre the butt over the hole and it was lowered slowly until it was just above the bronze pin. It was then centred carefully and lowered again—the pin served its purpose well and the pole grounded in its correct position. It had still to face in the right direction and this was done by using a parbuckling tackle round the butt.

Representatives from the School of Military Survey then helped, with two theodolites at right-angles, to check that the pole was vertical (the sloping ground and trees gave rise to an optical illusion that it was not). By adjustment of the pole guys it was moved until it was vertical within about an inch at the top.

A rapid hardening cement grout was then prepared as dry as possible to fill in the gap between the butt and the concrete annulus. We were again fortunate in that rain which had threatened all day held off until the work was completed.

Dismantling

Dismantling of the derricks began the following day and was quickly completed although we now had almost continuous rain. Park pickets were removed three at a time without damage by the Coles crane. (The crane had been most useful on a variety of tasks throughout the operation although it had naturally a tendency to bog on soft ground.) When the grout had hardened the waterproof sealing compound was applied and on 28th June the guys were removed leaving the pole unsupported. How to remove the guys—they were attached 75 ft. above the ground—had long exercised our minds but we were fortunate in the end in borrowing a 100-ft. fire escape from the fire station at Slough. Even then the S.S.M., perched on a small and swaying platform, was glad of his parachute training as he cut away the shackles one by one.

Epilogue

On 19th July, fifty members of 3rd Field Squadron together with representatives from 6 Field Park Squadron were present in uniform in Windsor Great Park when the totem pole was accepted by Her Majesty The Queen Mother, on behalf of Her Majesty The Queen, from the Agent General for British Columbia. Lieut.-Colonel E. M. Hall, M.B.E., R.E., commanding 22nd Field Engineer Regiment and representing the Corps was presented. Chief Mungo Martin, who carved the pole, was there and accepted a shield from Lieut.-Colonel Hall to mark the occasion.

The last sentence of an explanatory notice posted near the pole reads:—

"*It was erected by the 3rd Field Squadron of the 22nd Field Engineer Regiment Royal Engineers for their Colonel-in-Chief HER MAJESTY QUEEN ELIZABETH II in June, 1958. It also serves to symbolize the close association between British Columbia and the Corps of Royal Engineers who under Lt.-Col. R. C. Moody, R.E. actively engaged in the development of the colony in the years 1858 to 1863.*"

The Revised Code of Practice for the Use of Reinforced Concrete in Buildings*

By Major C. R. Scott, B.A., A.M.I.C.E., R.E.

In June, 1957, the British Standards Institution issued a revision of Code of Practice 114 for the "Structural Use of Reinforced Concrete in Buildings". In due course M.E., Volume XIV, Part II will be revised to conform to the new code, but as it is likely to be some time before the new edition is available some preliminary notes may be of interest.

The new code contains a number of detailed alterations embodying experience gained in the operation of the 1948 edition, but there are three changes of major importance. These are:—

(*a*) Changes in permissible stresses in steel reinforcement.

(*b*) Greater latitude in the design of concrete mixes.

(*c*) An alternative method of design based on a "load factor" rather than on a "factor of safety".

*An explanation of the symbols used in the text will be found at Appendix II.

Changes in the Permissible Stresses in Steel Reinforcement

The new permissible stresses are set out in Table 1, and need little further comment. It will be seen that:—

(*a*) The permissible stress in mild steel has been increased from 18,000 lb./sq. in. to 20,000 lb./sq. in. and there is a corresponding increase in the upper limit of permissible tensile stress in high tensile steels.

(*b*) The permissible stress in mild steel in compression is less than that for mild steel in tension.

(*c*) The permissible stresses in mild steel bars over $1\frac{1}{2}$ in. in diameter are less than those in bars of $1\frac{1}{2}$ in. diameter or less.

The general result of these changes will be a small but useful reduction in the total steel required.

Table 1. Permissible Stresses in Steel Reinforcement

Designation of stress	Permissible Stress		
	Mild steel to BS785 with no guaranteed yield stress		All steels with guaranteed yield stress
	Bar sizes	Stress lb./sq. in.	lb./sq. in.
Tension	Up to and including $1\frac{1}{2}$ in.	20,000	Half the guaranteed yield stress but not more than 30,000
	Over $1\frac{1}{2}$ in.	18,000	Nor in shear reinforcement more than 20,000
Compression (in bars other than twin twisted bars)*	Up to and including $1\frac{1}{2}$ in.	18,000	Half the guaranteed yield stress but not more than 23,000
	Over $1\frac{1}{2}$ in.	16,000	

*In twin twisted bars, each bar is curved so that under compression the bars tend to buckle more than straight bars.

Greater Latitude in the Design of Concrete Mixes

Considerable improvements have been made in recent years in the design of concrete mixes and in the control of mixing and placing. However, the 1948 code virtually specified the mix in terms of the cement content, which is by no means the only factor determining the strength and durability of the resulting concrete. Although minimum strengths were also laid down, they were generally low by modern standards, and it was not uncommon for the specified strength to be consistently exceeded by 30 per cent or more. In such a case the cement content could clearly be reduced but the specification generally forbade this, and there was thus little incentive to insist on high standards of workmanship. This has been recognized for some time and a growing number of specifications have allowed the mix (including the cement content) to be varied within broad limits and under proper safeguards, provided that the required strength was obtained.

Tables 2 and 3 show how provision is now made for this type of specification. Table 2 shows the permissible stresses in terms of the cube strength at twenty-eight days. Table 3 shows the broad limits within which the mix may be varied. This alteration should lead to greater economy but closer supervision and control of the work is required. Weigh batching is essential.

Table 2
Permissible stresses for special concrete mixes

Cube strength within 28 days after mixing		Permissible concrete stress in compression	
Preliminary test	Works test Cu	Direct	Due to bending
4_c	3_c	076_c	c

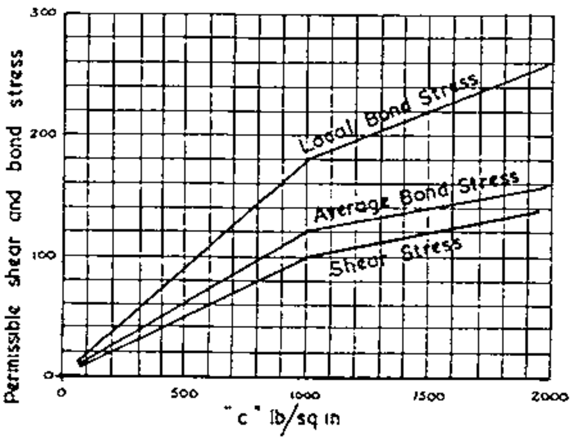


TABLE 3. STRENGTH REQUIREMENTS FOR SPECIAL CONCRETE MIXES

Mix proportions (cement to total aggregate by weight)	Cube strength	
	Preliminary test	Works test
(1)	(2) lb./sq. in.	(3) lb./sq. in.
For portland cement and portland blast furnace cement concrete, not leaner than 1 to 8 with a maximum size of aggregate of $\frac{3}{4}$ in. and 1 to 9 with a maximum size of aggregate of $1\frac{1}{2}$ in.; and designed for the required concrete strength at 28 days* within the range given in column (3)	$1\frac{1}{3}$ times the required works cube strength	2,250 to 6,000 at 28 days
For high alumina cement concrete not leaner than 1 to 8 not richer than 1 to 5, and designed for the required strength at 2 days, within the range given in column (3)	$1\frac{1}{3}$ times the required works cube strength	5,000 to 6,000 at 2 days

*Concrete may be deemed to be satisfactory if the seven-day cube strength is at least two thirds of the required twenty-eight day strength.

Load Factor Method of Design—General

Normal elastic design is based on a consideration of the behaviour of the materials under normal working conditions. Safety is ensured by limiting the stresses in the materials to a known proportion of their ultimate strength. This proportion is known as the "factor of safety".

Under normal working loads the materials may fairly be assumed to behave elastically. We are, however, more concerned with the behaviour of the materials immediately before failure, since the purpose of design is to prevent such failure. Under these conditions concrete does not behave elastically.

Load factor design is based on a consideration of the behaviour of the materials at failure. Safety is ensured by limiting the loads to a known proportion of the load which would cause failure. This proportion is known as the "load factor".

A code of practice is not a text book, and the design methods are generally stated without much explanation of the theoretical and practical considerations on which they are based. Moreover in this case the formulae have been stated in terms of the permissible stresses under working loads, which at first sight would seem to have nothing to do with a load factor design. To appreciate fully the advantages and limitations of the new method we shall have to look rather more closely at the theory behind it.

Before we consider this, two points must be made. Firstly, the load factor method is only an alternative, and the conventional method based on elastic theory may still be used if the designer so wishes. Secondly, every design consists essentially of two parts—the calculation of the moments and shears on any section, and the design of the section to resist them. In the light of present knowledge it is not possible to use a load factor design method to find the moments and shears, and this must still be done by methods based on elastic theory. The load factor method will therefore only be applied to the design of the section.

Load Factor Design of Rectangular Beams

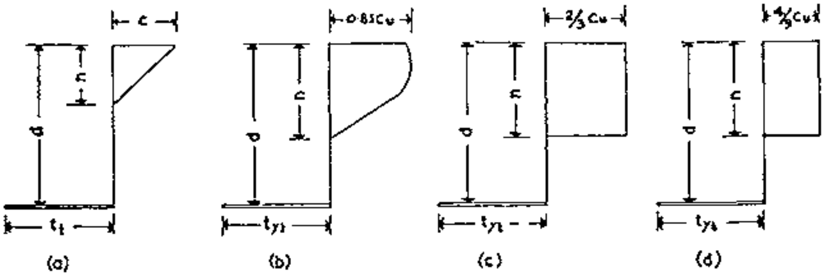


Figure 1

Stress distribution in concrete members in bending

The distribution of stress usually assumed in elastic design is shown in Fig. 1 (*a*). This is reasonably true under working loads but is not true at failure. The true distribution of stress at failure is shown approximately in Fig. 1 (*b*). The actual shape of the curve is difficult to determine and is of no practical importance. Experiment has shown that the assumed stress diagram shown in Fig. 1 (*c*) gives values of the ultimate strength of the section which are very close to the truth.

The load factor

The factors of safety used in elastic design are 2 for stresses in steel and 3 for stresses in concrete, and we should like to use similar load factors. A load factor can, however, only be applied to the section as a whole and we cannot use different load factors for the different materials in it. If, then, we assume an ultimate strength of concrete in compression of only 2/3 of its real value and then apply a load factor of 2, this will have the desired effect. The assumed mean stress in the concrete is now $2/3 \times 2/3 \times C_u = \frac{4}{9} C_u$. (See Fig. 1 (*d*).)

Limit to the plastic yield of concrete

The stress distribution shown in Fig. 1 (*b*) is caused by the plastic yield of the concrete. With a steel joist very considerable plastic deformation can take place without any loss of strength but with a concrete member this is not possible. Excessive strain of the concrete causes crushing and failure.

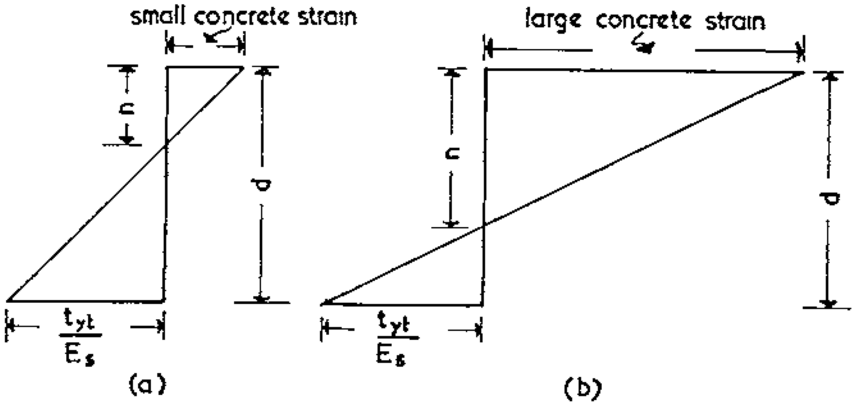


Figure 2

It will be seen from Fig. 2 that, for any given strain in the steel the strain in the concrete depends on the depth "n" of the neutral axis, and it is found in practice that a value of $n = \frac{d}{2}$ corresponds to the practical limit of the strain in the concrete. We therefore limit "n" to this value.

Stress in compression steel

In elastic design we limit the stress in compression steel to the stress in the surrounding concrete multiplied by the modular ratio (m), but before the section fails plastic yield of the concrete will have caused the steel stress to increase well beyond this figure. There is a limit to the possible stress in the steel since the safe strain in the concrete must not be exceeded. It is found in practice that this implies a stress in compression steel at failure of *either* the yield stress

$$or \quad 100000 \left(1 - \frac{d^1}{n}\right)$$

the latter expression should always be checked but will seldom be less than the yield stress.

Moment of resistance of under reinforced beams

In this case the strength of the tensile steel limits the strength of the section.

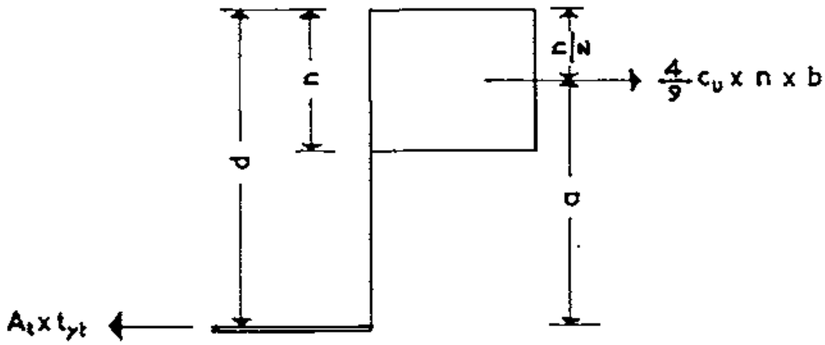


Figure 3

Equating the tensile and compressive forces:—

At failure $A_t \times t_{yt} = n \times b \times \frac{4}{9} C_u$

$$\therefore n = \frac{9}{4} \times \frac{A_t}{b} \times \frac{t_{yt}}{C_u}$$

$$\therefore a = d - \frac{n}{2} = d - \frac{9}{4}\frac{A_t}{2b} \times \frac{t_{yt}}{C_u}$$

Ultimate moment of resistance $= A_t \times t_{yt} \times a$

Allowing a load factor of 2

Working moment of resistance $= \frac{1}{2} A_t t_{yt} \times a$

But $\frac{t_{yt}}{2} = t_t$ (permissible tensile stress in steel. See table 1)*

$\frac{C_u}{3} = c$ (permissible compressive stress in concrete).

$\therefore$ Working moment of resistance $= A_t \times t_t \times a$

$$\text{Where } a = d - \frac{3A_t}{4b} \times \frac{t_t}{c}$$

Example 1 (in the Appendix) shows that both methods produce almost identical results in this case.

* This is only approximately true for mild steel which has no guaranteed yield stress. It is not true for steels with yield points in excess of 60,000 lb./sq. in., but in this case there are no other reasons for limiting the permissible stresses under working loads.

Moment of resistance of an economically reinforced beam

In this case compression concrete limits the strength

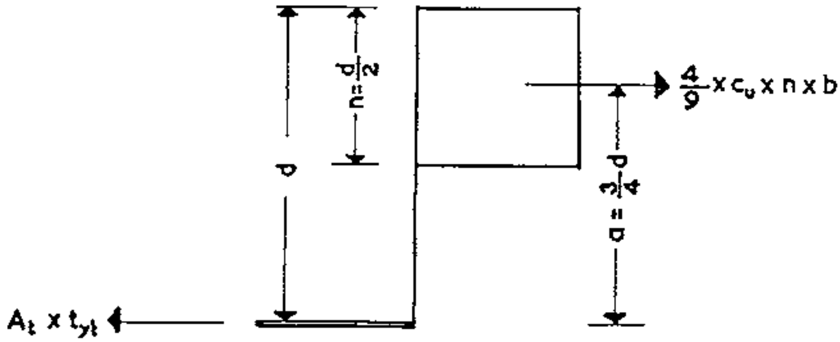


Figure 4

Max value of $n = \frac{d}{2}$ $\quad \therefore a = \frac{3d}{4}$

Ultimate moment of resistance $= n \times b \times \frac{4}{9} C_u \times a$

Taking a load factor of 2

Working moment of resistance $= \frac{1}{2} \times n \times b \times \frac{4}{9} C_u \times a$

$$= \frac{1}{2} \times \frac{d}{2} \times b \times \frac{4}{9} C_u \times \frac{3d}{4}$$

But $\frac{C_u}{3} = c$ (permissible stress in concrete in bending).

$\therefore$ Working moment of resistance $= \frac{c}{4} bd^2$

Example 2 shows that some reduction in depth can be made in this case but only at the cost of additional steel.

Moment of resistance of a doubly reinforced beam

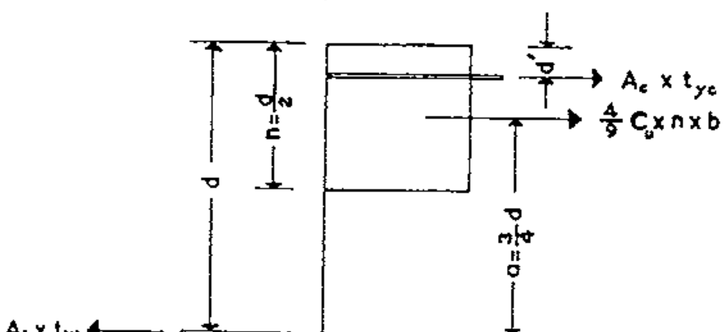


Figure 5

As before $n = \frac{d}{2}$ and $a = \frac{3d}{4}$

Taking moments about the centroid of the tensile steel

Ultimate moment of resistance $= n \times b \times \frac{4}{9} C_u \times \frac{3d}{4} + A_c t_{yc} (d - d^1)$

$\therefore$ Working moment of resistance $= \frac{c}{4} bd^2 + A_c \times t_c (d - d^1)$

Examples 3 and 4 show the very considerable economies in steel which result from the use of the load factor design in these cases.

T and L beams

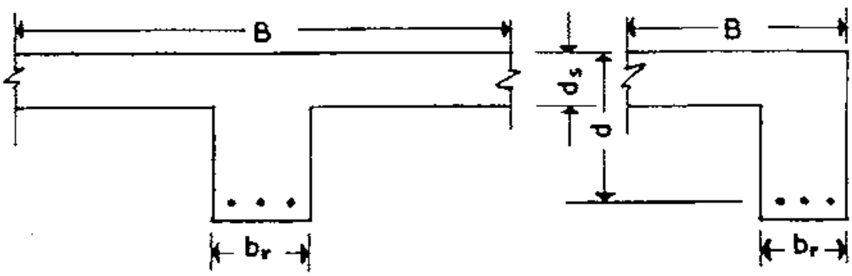


Figure 6

In the majority of large floor beams or bridge decks the strength of the tensile steel is the limiting condition. In this case the assumption is made that the length of the lever arm $a = d - \frac{d_s}{2}$. This is the same assumption as is made in the elastic method of design, and the expression for the moment of resistance is therefore also the same.

Working moment of resistance $= A_t \times t_{yt} \left(d - \frac{d_s}{2}\right)$

In some light ribbed or hollow block floors the strength is limited by the strength of the compression concrete. In this case, by the same reasoning as was used for rectangular beams we obtain the expression:—

Working moment of resistance $= \gamma c\ bd^2$

Where γ has the value given in Table 4.

The load factor design would allow some increase in load in this case although this is small if the section is slender.

Thus if $\frac{b_r}{B} = \frac{d_s}{d} = \frac{1}{6}$ the increase is about 2 per cent

if $\frac{b_r}{B} = \frac{d_s}{d} = \frac{1}{4}$ the increase is about 10 per cent

TABLE 4. MOMENT OF RESISTANCE OF T AND L BEAMS

$$\gamma = \frac{b_r}{B} - \frac{1}{3}\left(1 - \frac{b_r}{B}\right)\left(\frac{2d_s}{d} - \left(\frac{d_s}{d}\right)^2\right)$$

$\frac{B}{b_r}$	Values of γ for d/d_s					
	2 or less	3	4	5	6	∞
1	0.25	0.25	0.25	0.25	0.25	0.25
2	0.25	0.22	0.20	0.185	0.175	0.125
4	0.25	0.20	0.17	0.15	0.14	0.062
6	0.25	0.195	0.165	0.14	0.125	0.042
8	0.25	0.19	0.16	0.135	0.12	0.031
∞	0.25	0.185	0.145	0.12	0.10	0

LOAD FACTOR DESIGN OF COLUMNS

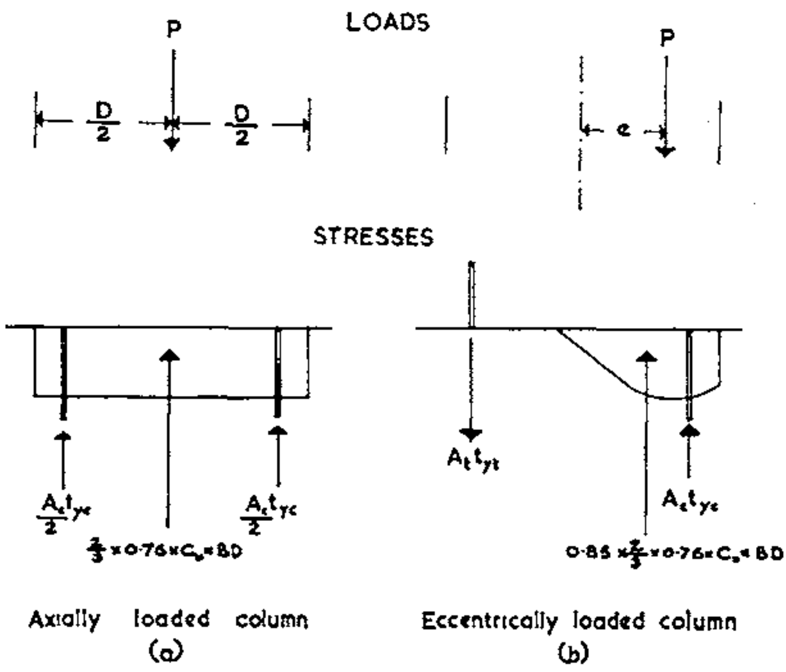


Figure 7

The assumptions made in the design of columns are:—

(*a*) The cube strength is taken as 0.76 of its real value

(*b*) the maximum compressive stress in the concrete is $\frac{2}{3}$ of the assumed cube stress (i.e. $\frac{2}{3} \times 0.76 \times C_u$)

(*c*) for an axially loaded column the stress diagram is rectangular (see Fig. 7 (*a*))

(*d*) for an eccentrically loaded column the stress diagram is a curve (see Fig. 7 (*b*)) such that:—

(i) the mean value = 0.85 of the maximum value

$$= 0.85 \times \frac{2}{3} \times 0.76 \times C_u$$

(ii) the centroid is at a depth of 0.425 n

(*e*) the maximum strain in the concrete is 0.33 per cent.

Safe load on an axially loaded column (P_o)

The assumptions given above lead to a value of the safe load:—

$P_o = A \times c + A_c \times t_c$ where A is the NET area of concrete

This is identical with the expression used in the conventional method of design.

Safe balancing load on a column (P_b)

The balancing load is the eccentric load which will just cause the compression and tension sides of the column to fail together.

The assumptions stated above lead to the expression

$$P_b = cBd\,X - A_c\,(t_t - t_c)$$

$$\text{whence } X = \frac{85000}{100000 + 2t_c}$$

and the corresponding eccentricity of the load e_b is given by the expression:—

$$P_b\left(e_b - \frac{d - d^1}{2}\right) = cBd^2 X\left(1 - \frac{X}{2}\right) + A_c t_c\,(d - d^1)$$

Safe eccentric load (P) *where* $e < e_b$

In this case the compressive strength of the concrete is the limiting factor.

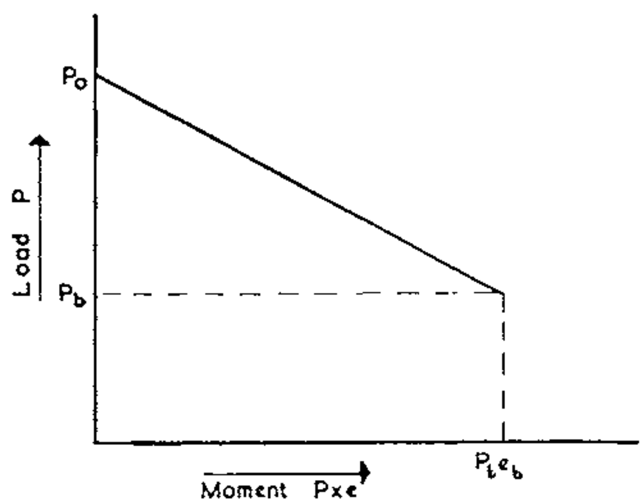


Figure 8

The permissible load is found by direct linear interpolation between P_o and P_b as shown in Fig. 8. There is no theoretical justification for this but a more rigorous analysis would only result in an expression which when plotted on Fig. 8 would be almost indistinguishable from the straight line drawn.

The equation of this straight line is:—

$$P = \frac{P_o}{1 + \left(\frac{P_o}{P_b} - 1\right)\frac{e}{e_b}}$$

Safe eccentric load (P) where $e > e_b$

In this case the tensile steel would be the first to fail.

The assumptions given above yield the rather unpromising expression:—

$$P = cBD\left(\left(0.5 - \frac{e}{D} - Y\right) + \sqrt{\left(0.5 - \frac{e}{D} - Y\right)^2 + \frac{rt_c}{c}\left(\frac{d - d^1}{D}\right) + Y\left(\frac{2d}{D} - Y\right)}\right)$$

where $Y = \frac{r}{2}\left(\frac{t_t - t_c}{c}\right)$

and $r = \frac{\text{Steel area}}{BD}$

Example on column design

As with elastic design the formulae do not lend themselves easily to direct calculation. They would normally be used to prepare tables from which required sections could be selected.

As a comparison between the methods the following figures have been calculated using the expressions obtained above.

(*a*) For a 10 in. × 10 in. column with 1 per cent of longitudinal steel reinforcement

e (in.)	*Safe load (elastic design) lb.*	*Safe load (load factor design) lb.*
0	93000	93000
2	52000	56500
4($\simeq e_b$)	32000	40500
6	21000	22500

(*b*) For a 10 × 10 in. column with 4 per cent of longitudinal steel

e (in.)	*Safe load (elastic design) lb.*	*Safe load (load factor design) lb.*
0	147500	147500
5	44500	66000
10 ($\simeq e_b$)	25000	37500
15	17000	20000

It is clear that the load factor design allows greater loads on eccentrically loaded columns. This is greatest when $e = e_b$ and is greater for columns with higher proportions of longitudinal steel.

Conclusions

The provisions of the new code of practice can result in considerable overall economies in the use of materials as compared with the previous edition. In particular, the load factor method of design results in a very useful reduction in the amount of steel required in heavily reinforced beams and columns. This is not only important from the point of view of cost: it is often difficult with such members to fit the required amount of steel into the section. The calculation involved is no more than with the conventional elastic design method.

Acknowledgement

The information contained in Tables 1 to 4 is reproduced from Code of Practice 114 by permission of the British Standards Institution. The copies of the full Code may be obtained from the Institution, 2 Park Street, London, W.1, price 10s.

References

Further information on the application of the new code may be found in:—

Reinforced Concrete Designers Handbook (5th Edition, 1957), by C. E. Reynolds (Concrete Publications Ltd.).

Explanatory Handbook on the BS Code of Practice for Reinforced Concrete (3rd Edition 1957), by Scott, Glanville and Thomas (Concrete Publications Ltd.).

Load Factor Design in Building Regulations: Future British Practice by D. D. Mathews (Symposium on the Strength of Concrete Structures: Cement and Concrete Association).

Beams and Slabs Designed by the Load Factor Method by C. E. Reynolds (Concrete and Constructional Engineering, May and June, 1958).

APPENDIX I

Examples on the Design of Rectangular Beams by the Load Factor Method

General Problem

A reinforced concrete beam is to carry 1,200,000 lb.-in. bending moment (including dead weight).

Permissible stresses are:—

$c = 1000$ (i.e. a 1 : 2 : 4 nominal mix)

$t_t = 20000$ } (i.e. mild steel to BS785 up to $1\frac{1}{2}$ in.

$t_c = 18000$ } diameter).

Example 1. An under reinforced beam

The beam is to be 12 in. wide and 24 in. in effective depth.

Elastic design	*Load factor design*
$n = \dfrac{d}{I + \dfrac{t_t}{mc}} = \dfrac{3}{7}d$	$a = d - \dfrac{3}{4}\dfrac{A_t}{b} \times \dfrac{t_t}{c}$ $= 24 - \dfrac{3}{4}\dfrac{A_t}{12} \times \dfrac{20000}{1000}$
$a = d - \dfrac{n}{3} = \dfrac{6}{7}d$	$= 24 - \dfrac{5}{4}A_t$
Moment of resistance $= 1200000$ $= A_t \times t_t \times a$	Moment of resistance $= 1200000$ $= A_t \times t_t \times a$
$\therefore A_t = \dfrac{1200000 \times 7}{20000 \times 24 \times 6}$	$\therefore 1200000 = A_t \times 20000\,(24 - \dfrac{5}{4}A_t)$
	$\therefore \dfrac{5}{4}A_t^2 - 24A_t + 60 = 0$
$= \underline{2.92 \text{ sq. in.}}$	$\therefore A_t = \underline{2.96 \text{ sq. in.}}$

Example 2. An economically reinforced beam

The beam is to be 12 in. wide and is unrestricted in depth. What is the depth required for economical design and how much tensile steel is required?

Elastic design

As before $n = \frac{3}{7}d$

$a = \frac{6}{7}d$

Moment of resistance $= \frac{1}{2}\,cnba$

$= \frac{1}{2} \times 1000 \times \frac{3}{7}d \times b \times \frac{6}{7}d$

$= 184bd^2$ lb.-in.

$\therefore 1200000 = 184 \times 12 \times d^2$

$\therefore d = \sqrt{\frac{1200000}{184 \times 12}}$

$= \underline{23.3 \text{ in.}}$

$A_t = \frac{1200000 \times 7}{20000 \times 23.3 \times 6}$

$= \underline{3.01 \text{ sq. in.}}$

Load factor design

$n = \frac{d}{2}$

$a = \frac{3}{4}d$

Moment of resistance $= \frac{c}{4}\,bd^2$

$= \frac{1000}{4}\,bd^2$

$= 250\,bd^2$ lb.-in.

$1200000 = 250\,bd^2$

$\therefore d = \sqrt{\frac{1200000}{250 \times 12}}$

$= \underline{20 \text{ in.}}$

$A_t = \frac{1200000 \times 4}{20000 \times 20 \times 3}$

$= \underline{4.00 \text{ sq. in.}}$

Example 3. A doubly reinforced beam

The beam is to be 12 in. wide and 21 in. in effective depth. The centroid of the compression steel is 2 in. from the edge of the beam. How much steel is required?

Elastic Design

$n = \frac{3}{7}\,d = 9$ in.

$a = \frac{6}{7}\,d$

Moment of resistance of concrete in compression $= 184\,bd^2$

$= 975000$ lb.-in.

Moment of resistance of compression steel

$= 1200000 - 975000$ lb.-in.

$= 225000$ lb.-in.

Stress in compression steel

$= 1000 \times 15 \left(1 - \frac{2}{9}\right)$

$= 11600$ lb./sq. in.

$A_c = \frac{225000}{11600\,(21 - 2)}$

$= \underline{1.02 \text{ sq. in.}}$

$A_t = \frac{1200000 \times 7}{2000 \times 21 \times 6}$

$= \underline{3.33 \text{ sq. in.}}$

Total steel $= \underline{4.35 \text{ sq. in.}}$

Load Factor Design

Moment of resistance of concrete in compression $= 250\,bd^2$

> 1200000 lb.-in.

$\therefore$ The beam is under reinforced and no compression steel is required.

$a = d - \frac{3}{4}\frac{A_t}{b} \times \frac{t_t}{c}$

$= 21 - \frac{3}{4} \times \frac{A_t}{12} \times \frac{20000}{1000}$

$= 21 - \frac{5}{4}\,A_t$

$\therefore 1200000 = A_t \times 20000 \left(21 - \frac{5}{4}A_t\right)$

$\therefore \frac{5}{4}\,A_t^2 - 21A_t + 60 = 0$

$\therefore A_t = \underline{3.64 \text{ sq. in.}}$

Total steel $= \underline{3.64 \text{ sq. in.}}$

Example 4. Doubly reinforced beam

The beam is to be 12 in. wide and 18 in. in effective depth. How much steel is required?

Elastic design

$$n = \frac{3}{7}d = 7.7 \text{ in.}$$

$$a = \frac{6}{7}d$$

Moment of resistance of concrete in compression $= 184bd^2$

$= 717000$ lb.-in.

Moment of resistance of compression steel $= 1200000 - 717000$

$= 483000$ lb.-in.

Stress in compression steel

$$= \left(1 - \frac{2}{7.7}\right) \times 1000 \times 15$$

$= 11100$ lb./sq. in.

$$A_c = \frac{483000}{11100\ (18 - 2)} = \underline{2.72 \text{ sq. in.}}$$

$$A_t = \frac{1200000 \times 7}{20000 \times 18 \times 6} = \underline{3.88 \text{ sq. in.}}$$

Total steel $= \underline{6.60 \text{ sq. in.}}$

Load factor design

$$n = \frac{d}{2}$$

$$a = \frac{3}{4}d$$

Moment of resistance of concrete in compression $= 250\ bd^2$

$= 975000$ lb.-in.

Moment of resistance of compression steel $= 1200000 - 975000$

$= 225000$ lb.-in.

Stress in compression steel

$$\text{either} = \tfrac{1}{2} \times 100000 \left(1 - \frac{2}{9}\right)$$

$= 39000$ lb./sq. in.

or $= 18000$ lb./sq. in.

$$A_c = \frac{225000}{18000\ (18 - 2)} = \underline{0.78 \text{ sq. in.}}$$

$$A_t = \frac{1200000 \times 3}{20000 \times 18 \times 4} = \underline{4.44 \text{ sq. in.}}$$

$= \underline{5.22 \text{ sq. in.}}$

APPENDIX II

LIST OF SYMBOLS USED IN THE TEXT

A_c = Area of compression steel
A_t = Area of tensile steel
a = Lever arm of the section
B = Flange breadth of a "T" or "L" beam
  Breadth of a column
b = Breadth of a beam
b_r = Rib breadth of a "T" or "L" beam
C_u = Ultimate strength of concrete in compression
c = Permissible stress in concrete in compression
D = Overall depth of a beam or column
d = Effective depth of a beam
d^1 = Depth to the compressive reinforcement in a beam
d_s = Slab depth in a "T" or "L" beam
E_c = Young's Modulus for concrete
E_s = Young's Modulus for steel
e = Eccentricity of the load on a column
n = Depth to the neutral axis
P = Permissible load on a column
t_c = Permissible stress in steel in compression
t_t = Permissible stress in steel in tension
t_{yc} = Yield stress in steel in compression
t_{yt} = Yield stress in steel in tension

Lake Padarn, 1958

An Account of the Construction of the Rowing Course for the British Empire and Commonwealth Games by 50 Field Squadron, R.E.

> "A massive contribution was made by the Royal Engineers, who marked out the course, built Judges and Press boxes to plan and to time, in the face of North Wales, with the same efficiency with which their fathers had built bridges over the Rhine under fire. They deserve much praise; and sympathy too, for the accident which caused the Judges' stand to sink."—*The Field.*

It did not in fact sink, but "waterlogged" is a cumbersome word and not nearly so dramatic as the incident deserved—but that is at the end of the story.

It was perhaps fortunate that there were no manuals or R.E. training memoranda to tell one how to build a 2,000 metre rowing course to international standards. Nature whenever she achieves disaster generally manages to do so by the application of wind and water in really quite basic ways. By having to plan from first principles it was possible to design and order roughly what was best suited to meet the weather in all its moods. That events showed up certain chinks in the armour could perhaps be attributed to the fact that Nature had been playing the game rather longer.

The Task

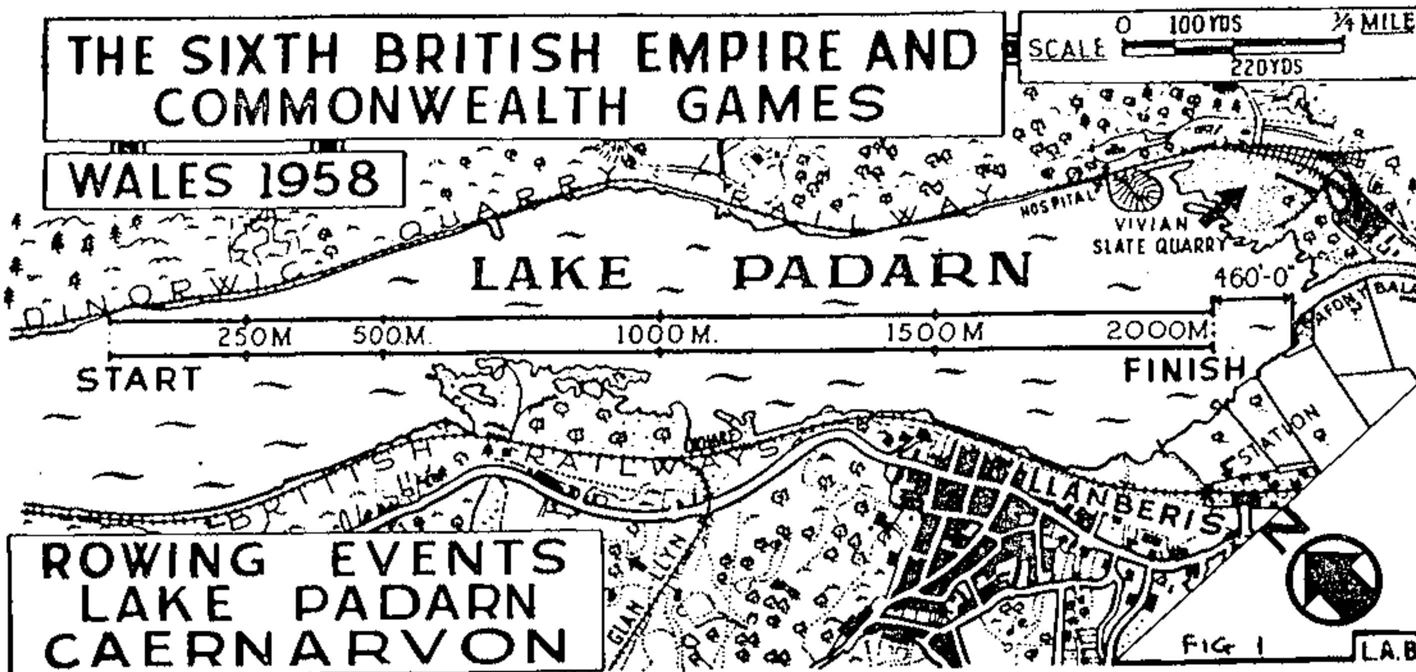
The initial requirements were simple. A start and a finish line exactly 2,000 metres apart, two lines of buoys, 60 metres apart, to mark the edges of the course, and overhead wires strung across the course at seven places to support 2-ft. diameter coloured plastic balls 15 ft. above the water to mark the lanes, and last, but by no means least, floating grandstands on the finish line for Judges, B.B.C. and the Press.

As with most simple problems the main difficulty was in deciding which of the thousand and one easy solutions to adopt.

Lake Padarn, at the foot of Snowdon, had already been chosen as the site and the course roughly pencilled in on the 6-in. map by the Games Rowing Committee in February, 1958, whilst 25 Corps Engineer Regiment, of which 50 Field Squadron was a part, were still on their way back from Christmas Island.

The lake is narrow and deep and about two miles long. The rocky sides shelve steeply in a series of steps and ledges to depths of between sixty and ninety feet, as one might expect from a worked-out and inundated slate quarry. It is fed and emptied by a stream at either end and its level is uncontrolled by man.

Flat slabs of slate and granite covered with a few inches of slime will not hold an anchor, and the designers were thus presented with their first limiting factor. The only other design restriction was economy. The Games Committee were to be charged for everything that was consumed, lost or damaged, and for fuel used in excess of the normal summer training allotment. No charge was to be raised for the hire of army equipment but movement of men and engineer stores had to be billed to the Games.


THE SIXTH BRITISH EMPIRE AND COMMONWEALTH GAMES
WALES 1958
SCALE
0
100 YDS
220 YDS
¼ MILE
LAKE PADARN
DINORWIC QUARRY
RAILWAY
HOSPITAL
VIVIAN SLATE QUARRY
460'-0"
AFON Y BALA
250M
500M.
1000 M.
1500 M
2000M.
START
FINISH
BRITISH RAILWAYS
STATION
LLANBERIS
GLAN LLYN
N
FIG 1
L.A.B.
ROWING EVENTS
LAKE PADARN
CAERNARVON

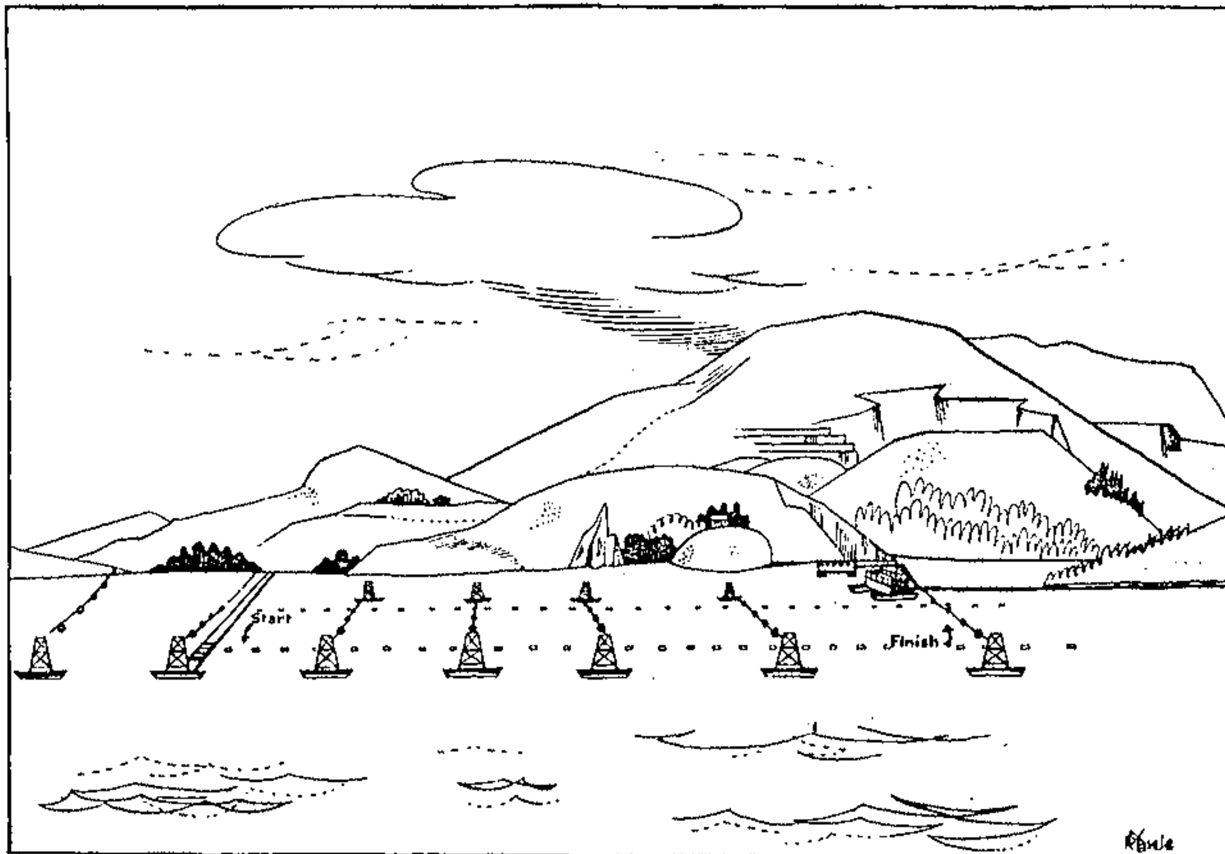


Fig. 2.

The main design problem was the suspension of the overhead markers 15 ft. above the water, and there was no alternative but to make some form of floating tower to carry the cable. After a few trials of various types of standard equipment at Wouldham it was decided that a tubular steel scaffolding tower mounted on a Class 5 folding boat raft gave the optimum combination of stability, ease of construction and minimum weight and volume for transportation to site. Two Bailey pontoon rafts were chosen as the basic structure for the Press and Judges' rafts. Design work was completed by the end of April and final stores lists submitted to Command Headquarters in the first week of May.

A brief comparison of planned and actual happenings gives an idea of the way in which nature abhors a vacuum—in this case the planners' overinsurance in time for "contingencies":—

Planned events	*Actual events*
27th May. Advance party to Llanberis 29th May. Accommodation stores arrive 2nd June. Main body to Llanberis 2nd–5th June. Engineer stores arrive 3rd–20th June. Construction of Course	As planned except for motor-boats which did not arrive until 11th June.
21st June. 3 Tp. and married men to Maidstone	21st June. All complete except carpentry on Bailey rafts and fixing of overhead markers not delivered by makers.
21st June–4th July Maintenance and contingencies	26th June. "The storm". Five rafts sunk in 80 ft. of water 27th June–3rd July. All rafts successfully salvaged.
4th July	4th July. Course rebuilt.
5th July. Teams start training	5th July. Teams start training.
19th July 21st July 22nd July — Empire Games—Rowing Events	As planned except for accident to Judge's raft on final day.

Whilst at Llanberis the Squadron lived in a disused R.A.F. Bomb Disposal camp on the outskirts of the village. Accommodation was short, with officers and sergeants living under canvas, and cooking and washing facilities definitely on an austerity level. Fortunately the Squadron was very rapidly adopted by the villagers, who with their very open hospitality and keen interest in the task more than amply compensated for any feeling of homesickness.

Construction

The map of Lake Padarn at Fig. 1 and the diagram at Fig. 2 give an impression of the completed task.

The building hard, a strip of meadow the size of the centre court at Wimbledon, was entered by a level crossing almost in the centre of the village. As passenger trains only run in the summer season which starts in mid-June, there was the need to persuade the engine driver of the goods train which brought the engineer stores to park his train on the level crossing so that the Coles crane could unload directly on to the hard. This point was not achieved without a certain amount of discussion between the Squadron 2 i/c and the engine driver, the latter being averse to stopping on the crossing as it apparently contravened some railway regulation about halting outside the station limits. However, one of the several villagers present at this discussion (in an entirely unofficial capacity) was as anxious as the Squadron to see the work started, and pointed out to the assembly that the driver was in the habit of parking his engine on the level crossing so that his fireman could run up to the village to collect their fish and chips of an evening. With precedent thus established the day was won.

Except for the hard and a few yards of foreshore at the north-west end, the lake is inaccessible by road and is bounded on both sides by railway lines. This meant that both men and equipment had to be ferried to site, and for the anchorages that required a rock drill the compressor had to be operated from a raft.

Survey started as soon as the advance party arrived, and by the time the main body was ready to begin work, the start line and the anchorages for longitudinal cables had been pin pointed.

The course itself consisted of two longitudinal cables of 1½ in. S.W.R. 70 metres apart which ran almost the full length of the lake and to which were fixed the rafts. The ends of these cables were taken to hand winches held back by a double V system of ordnance pattern holdfasts at the meadow end of the lake and to ring bolts set in the rock at the north-west end. The rafts were then positioned laterally by 1-in. S.W.R. to similar winches on the lake side. The system was kept in a state of stable equilibrium by the overhead marker wire which was stretched between the towers of every pair of rafts and held taut by 400 lb. concrete cubes hanging over snatch blocks. (Fig. 3.) page 405.

The Squadron, on lower establishment, had two troops only, each troop being about twenty-five strong, but this proved to be quite ample for the task. Whilst one troop concentrated on laying the cables and setting out the anchorages, the other built the rafts and towers and handed them over to the first troop for positioning when ready. Survey continued throughout construction and was given invaluable assistance by the Squadron signals section of six sappers with man-pack sets. Four of these were in continual operation and were generally allotted on the basis of one to each bank, one as O.C.'s rover, and one with the second in command in the squadron office back in camp.

No major snags were met with in the initial construction work, thanks very largely to excellent stores forecasting by the second in command, Fred Beringer, and the very special care that had obviously been taken by the Engineer Resources organization at Chester and Long Marston to ensure that we got the very best they had. Credit too must also go to the troop officer surveyors, Vick Freeman and Geoff Thomas, who in spite of talking to each other all day and most of the night in the strange language of seven figure log tables, chains and traverses, were still able at the end of the day to explain to their O.C. what they had achieved in simple enough language for him to understand without giving him too much of an inferiority complex.

In order to reduce construction time on the tubular steel scaffolding towers, the troop concerned built a jig on the ground on which to prefabricate a complete side of the tower. The sides when ready were passed to another party which joined four of them together to make the tower. This was then walked bodily on to the raft which was tied up close to the hard. For this operation the clamp men were armed with adjustable spanners which are quite the worst possible tool for the job. The fumbling they produced was very clearly noticeable by comparison with the efforts of a civil firm of scaffold erectors who were building the grandstands. Each civilian erector was equipped with a tool like a plug spanner with a built-in swivel tommy bar and could tighten a clamp in about ten seconds. The Squadron was just about to "keep up with the Joneses" by local purchase when it was discovered that the army clamps came in about three different sizes of nut, for which the adjustable spanner was, after all, a logical solution.

The following brief extracts from the daily situation reports give an idea of the problems met with during the first ten days.

2nd June

With the arrival of the main body by train at 2030 hrs. the Squadron was complete at Llanberis. The majority of the project stores had arrived by train during the day and had been unloaded by the advance party. The motorboats, outboards and mechanical pumps were expected on the 5th June but sufficient stores had arrived for work to start on the following day.

3rd June

Very heavy rain fell all night and continued without a break until midday. Work nevertheless continued and it was interesting to note how rapidly a lake of this size could rise 4 inches.

Survey went on and all longitudinal anchorages had by this time been spot marked. All the Bailey pontoons and stormboats had been launched and 25 per cent of the F.B.E. boats uncrated and launched by the end of the day.

As a result of the overnight rain the Coles crane bogged itself up to the axles and, after five hours of experimenting with tackle and anchorages, pulled itself out by simultaneously motoring and hauling with its crane on a buried holdfast.

The unit canteen opened for the first time but the village was still a greater attraction.

4th June

The weather remained fine during the hours of daylight, the lake ceased to rise and work continued as planned. The drilling of holes in the rock outcrop on the north-west shore for ringbolt anchorages proceeded slowly during the day with the Worsop drill borrowed from one of the local quarries. Lack of road access to the anchorage sites had initially dictated this type of man-portable drill, but when the drill finally died at tea-time the decision was taken to load a Pescara compressor on an F.B.E. raft and operate it from a moored position alongside. The Pescara was embarked at 6 p.m. and was successfully tested on site at 8 p.m. before closing down for a fresh start the next morning.

Winches and miscellaneous stores were ferried to the various lateral anchorage sites throughout the day and by the evening all the rafts had been completed and anchored off-shore (anti-children) ready to be brought into the wharf in succession to have their scaffolding towers fixed.

5th June

After a rainy night the weather cleared at daybreak leaving a stiff breeze which blew down the length of the lake. This breeze ruled out any rowing of rafts and caused anchors to drag—the bottom being mostly of slate overlaid with a thin layer of mud and gravel offered very little resistance to the hundred-weight anchors in temporary use.

Drilling on the north-west longitudinal anchorages continued with the Pescara working well from its floating platform. The winches for the south-east longitudinal anchorages were bedded in and were 90 per cent secured by the close of play.

It was hoped that the tugs would have arrived by now (E.T.A. 2nd June) to cope with the cable laying task but they had been delayed at Queensferry due to defects and it was still not known when they would arrive. It was therefore decided to start laying the main cables from a F.B.E. raft towed by a storm boat.

Four towers were completed during the day. This figure would have been higher had the troop involved not had to divide its forces to unload a further stores train that arrived at midday.

6th June

Continuous wind and rain made working conditions very unpleasant and all ranks were soaked through within an hour of starting work. This did not affect the construction of towers but definitely hindered all boating such as the delivery of anchorage stores to sites around the lake. No attempt to lay cable was made on account of the wind and rough water. In the afternoon when the wind had died down slightly, the cable laying raft was used to assist in the ferrying of stores and on the last trip was blown against a rock. One of the F.B.E. boats was holed beneath the waterline but the N.C.O. in charge managed to beach it just before it sank. As the hole was comparatively small it was reckoned that a No. 5 pumping set would be able to beat the leak and that the raft could be refloated and towed the mile back to the hard. Unfortunately on arrival the pump was found to be almost completely without compression, and although it ran like a charm when not pumping, gave up the ghost completely when under load. The raft party then set-to with buckets and kept their craft afloat whilst it limped the mile back to the hard.

Eleven rafts and towers were completed by the end of the day.

8th June

The first longitudinal cable was laid with buoys attached at regular intervals with the intention of supporting the cable. Unfortunately they did not have sufficient buoyancy to achieve this and the buoys were carried down into deep water where the pressure crushed them. After paying out a quarter of the cable in this very laborious and fruitless fashion it was decided to forgo the buoys and to trust that the cable would not get inextricably snagged on the bottom when the time came to tighten it. For ease of laying the decision proved to be the right one, as it was found possible to tow the cable-laying raft at almost full speed, only two halts having to be made when it became necessary to shackle on fresh drums of cable.

9th June

The second longitudinal cable was laid successfully during the day and proved much easier than the first now that the men knew the drill. The slack had not yet been taken up at this stage but F.B.E. rafts had been threaded on to these cables to lift them clear of snags on the bottom so that they could be fixed to their final anchorages and hauled taut.

Work was started on the first of the two Bailey rafts for the Press and Judges' stands (Figs. 4, 5). Two Troop who were engaged on this task also unloaded 40 tons of railway ballast from a goods train on to muddy patches on the approach road to the hard.

10th June

Rag bolts at the north-west end of the lake had set firmly, and the outside raft cable was connected to them and the strain taken up. Work on the lateral anchorages went to schedule, although in several places there was insufficient space between the railway line and the lake edge to place the best type of anchorage. As these anchorages were not expected to take much strain it was not necessary to make them as robust as the longitudinal anchorages. Simultaneously with the placing of these anchorages, aiming posts were set up behind them so that raft commanders could locate themselves correctly.

The two longitudinal cables were winched tight during the day. Eleven F.B.E. rafts had by now been threaded on to these cables to keep them off the bottom and, as hoped, the cables automatically took up their correct alignment on tightening.

Work continued throughout the day on the construction of the second Bailey raft for the Judges' stand. The raft was basically single construction, but the end bay at one end had been given a second storey to provide a working platform for B.B.C. commentators. Because of soft ground at the hard it was not possible to bring the Coles crane to the waters edge, and construction of this raft had to be completed at the north-west end of the lake where the road ran a few feet from the water. When complete the raft was towed the 2 miles back to the hard (Figs. 4 and 5).

11th June

A penetrating drizzle all morning gave way at noon to a warm haze which continued throughout the day and was a great encouragement. The motor tugs arrived at long last by rail. As the bridging hard was soggy and incapable of supporting the crane, there was no alternative but to load the two tugs on to 3 tonners and take them to the north-west end of the lake for launching.

12th June

The Squadron was now engaged on two main tasks, positioning of F.B.E. rafts and building the wooden upperworks of the Bailey rafts.

The counterweight system for positioning the F.B.E. rafts was working well, and the overhead wire remained taught under all wave conditions.

The fourth longitudinal anchorage to take the last course marking cable had to be constructed out of mass concrete ($2\frac{1}{2}$ ft. cube) on the water's edge and keyed into the stacked slate railway embankment, as there was no firm rock at this particular point in which to drill holes and fix ringbolts. The concreting proved to be an interesting task as the lower eighth of the cube was below water level. Overhead cables for the back marker and the start line were fixed successfully during the day. Both cables were fixed directly to ringbolts in the cliff side and had to pass over the railway track. Limiting factors were:

(*a*) Cable to be not more than twenty feet above water level in order to be horizontal.

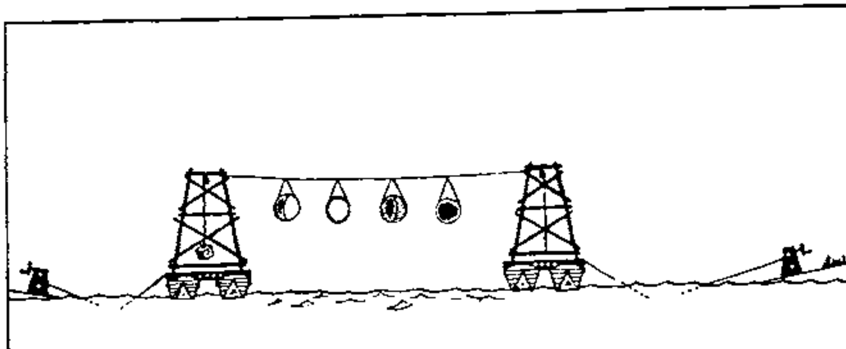


FIG 3

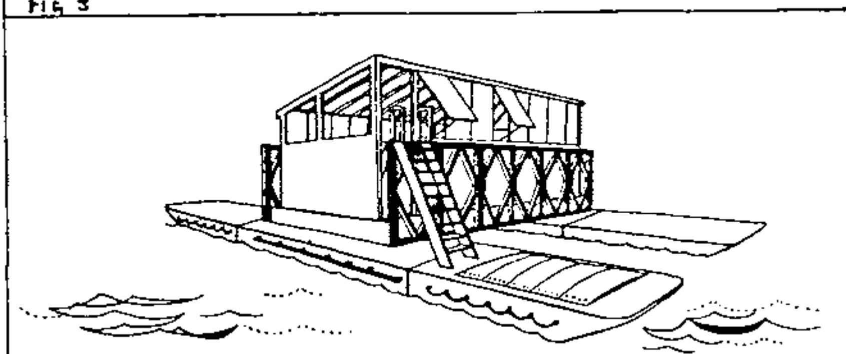


FIG 4 PRESS RAFT

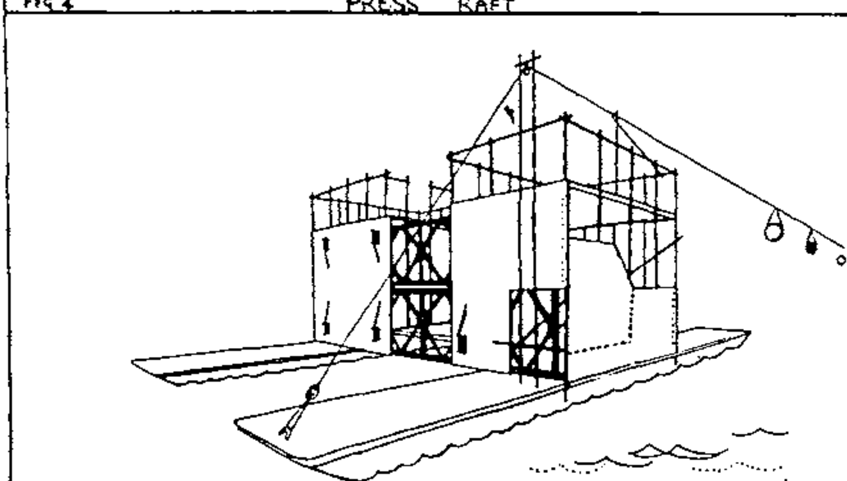


FIG 5 JUDGES RAFT

(*b*) Cable to be lower than the telephone lines under which it had to pass because of (*a*).

(*c*) Cable to be higher than the smoke stack of the local quarry train.

For the first trial the engine driver very kindly reduced speed to one puff per second and it was found that the stack cleared by half an inch. The factor of safety was subsequently increased.

The Lull

And so the Squadron went blissfully on with its work, and by 21st June the lake looked sufficiently like a rowing course for 3 Troop and the married men to return to Maidstone to resume normal training as planned. Captain Beringer with Squadron Headquarters and 2 Troop remained at Llanberis to put the final touches to the course and deal with day to day maintenance. The Squadron was feeling in particularly good heart at its achievements, which merely shows how dangerous pride can be.

The Storm

The soldierly pause between the first and second circuit of the port at a regimental guest night, with its muted air of bonhommie and complete inner conviction that all is indeed well with the world, is perhaps as good a time as any for a second in command to ring up his O.C. from 300 miles away to tell him that a minor hurricane was sweeping down the Llanberis pass and that the work of a fortnight was once more back at square one.

Changing out of mess kit and packing a bag at midnight to catch the Irish Mail at Euston at daybreak seemed unkind at the time, but fades into the shadows when compared with the overnight events at Lake Padarn. These were recorded by Fred Beringer in his sitrep for the day:—

"At approx. 1700 hrs. Wednesday, 25th June, 1958, I prepared to leave the hard. It was raining heavily but there was only a light breeze blowing. I arranged with Spr. Baker the tug operator to take Mr. Stobart* and myself out on the lake at 2030 hrs., and returned to camp. At approx. 1900 hrs. a message came for the Orderly Officer from the Guard Commander to the effect that the moored dinghy appeared to be in trouble. The Orderly Officer (2nd Lieutenant Weeden) immediately set off for the hard. The wind had risen by this time and tents had to be more firmly secured as they appeared to be in danger of "taking off". At about 1915 hrs. I set off for the hard to see the situation for myself, before meeting Mr. Stobart. On arrival at the hard I was met by Spr. Francis of the guard who told me that both the rafts at the 1,000 metre mark had sunk. There was in fact no sign of the rafts from the hard.

"There was now a full gale blowing down the lake from east to west. The wind was obviously being funnelled down the pass and was reaching high velocities down the lake. The lake was being whipped up and there was a high sea running. Meanwhile, 2nd Lieutenant Weeden had taken the Guard Commander out in the tug to see what could be done for the dinghy. The tug was trying to keep close to the shore but I could see she was shipping a great deal of water and not really riding the waves at all well. 2nd Lieutenant Weeden turned back and as soon as he reached the shore I immediately

*Chief Executive, Lake Padarn Committee.

ordered that no one was to go on the water until further notice. The gale continued to increase and the white topped waves were far too high for any of the squadron craft to tackle them. I estimated the waves at three to four feet high. 2nd Lieutenant Weeden had already ordered that the lateral cable to the 1,500 metre raft should be slackened off. I told him to continue down the line of the rafts slackening off all the lateral cables.

"I then sent a message back to camp to get the S.Q.M.S., Sergeant Burnett and as many men as possible to turn out on the hard.

"I drove to the west end of the lake to see what damage had been done there. The rafts were still intact but there was a great bow in the landing stage at the start of the course, which joins the start raft to the bank. I went back to camp and collected L/Corporal Summerson and one man and two handles for the winches. I dropped them off above the start line with the task of slackening the lateral cables along the course on the far side of the lake.

"I then returned to the hard to find Captain Pallant, the S.Q.M.S., Sergeant Burnett and about fifteen men. They were already at work beaching the stormboats and the tugs and pumping them out with a Johnston pump. I then met Mr. Stobart about 2030 hrs. and told him the damage. He entirely agreed with me that it was far too rough for any boats to go out. I left Captain Pallant in charge and took Sergeant Burnett with me through the quarries and along the north side of the lake. The longitudinal cables were holding well and after considering the situation with Sergeant Burnett I decided the situation would not be eased by slackening the longitudinal cables but might increase the danger to the rafts left floating.

"We worked our way along the north side and examined each of the winches. The rafts at 1,500 metres were shipping a great deal of water and waves were breaking right over the bows.

"We passed the two sunken rafts at 1,000 metres and could see no trace other than the lateral cable going down into the water. At 500 metres we discovered that the raft on the north side had sunk. At 250 metres the rafts were intact. At the start the landing stage had been badly bowed but the raft was still afloat. It was shipping a great deal of water.

"I tried to get down the landing stage to see if there would be any point in freeing the raft but it was so insecure I decided that discretion was the better part of valour and got back to land. The raft behind the start was shipping water as well but appeared in no great danger. I then returned to the hard with Sergeant Burnett to find that all the unit boats had been made secure and no damage done to the beached boats.

"At 0320 hrs. the following morning I did a recce. with Captain Pallant and Sergeant Burnett. At first light we discovered that the south raft at 1,500 metres and the start raft had gone making a total of five rafts sunk.

"The wind was still too high to start work but shortly after 0400 hrs. I took Sergeant Burnett and Sapper Baker and went out on the lake to start pumping out the rafts with the Johnston pump.

"At about 0630 hrs. I decided the weather had eased enough and general salvage could start. I therefore turned out the rest of the Squadron.

"A detailed reconnaissance revealed that five rafts had sunk, including that at the start which had carried with it half the catwalk, but all the essential cables appeared to be still intact.

"The day, a wet rainy one, was spent in pumping out all rafts still floating, locating sunken rafts and preparing the Press and Judges' rafts for salvage work."

Salvage

Of the five wrecks perhaps the most disturbing to see was the one at the start. The floating catwalk which ran from the shore to the raft and formed the startline had been broken in half by the storm, and the offshore end could be seen disappearing into the depths. The end of the catwalk was presumably still connected to the raft some forty feet below the surface. Of the other four rafts there was absolutely no trace as they all lay in 80 ft. of water.

As the raft at the start still had some residual buoyancy by virtue of its attendant catwalk, it was decided to start salvage there. There was every reason to believe that the longitudinal cable was still attached to each wreck, but as the attachment was through the fairleads of one of the two boats, extreme caution would have to be used not to wrench off the fairlead which was only riveted to the fabric of the boat. The longitudinal cable itself had also to be treated with respect as there was no indication of whether the strain, which was in places making the cable bar tight, was in fact critical.

During this first day of salvage, Thursday, 26th June, spare pontoon sections were pushed beneath the longitudinal cable on either side of the first wreck. They were then manhandled towards each other until the men were physically unable to pull any more. The pontoons were still over a hundred yards apart at this stage, and it was quite apparent that much heavier salvage craft would have to be used. Orders were then given for the Press and Judges' rafts to be released from their anchorages at the finish of the course and to be towed up to the start. On arrival at the site they were placed one on either side of the wreck and astride the longitudinal cable which was picked up on to snatch blocks slung beneath the centre panels. A winch was placed on the deck of each Bailey raft and the winch wires paid out until they met. They were then shackled together. A spare F.B.E. raft had picked up the lateral cable from the shore and by travelling down it as far as it could go towards the wreck, formed the third side of this salvage box. As it was by now 10 p.m. and the men had been working continuously for eighteen hours, it was decided not to attempt a lift until the following morning.

With the outcome of the salvage operations still unpredictable, alternative plans had to be made to ensure that whatever happened the course would be ready for the teams to start training on 5th July. An immediate order was therefore placed for stores to replace all five towers and rafts in case the wrecks could not be recovered, and it was calculated that salvage work could continue for another five days before the decision would have to be taken to cut adrift and start afresh. An offer by C.E. Eastern Command to provide a naval diving team was accepted with alacrity and Three Troop was recalled from Maidstone. This troop was unfortunately now at half strength as Geoff Thomas and twelve men had been diverted to South Wales to build a foot-bridge over the River Taff for the Cardiff end of the Empire Games—a commitment which 9th Airborne Squadron had had to abandon when they were flown to the Middle East at short notice.

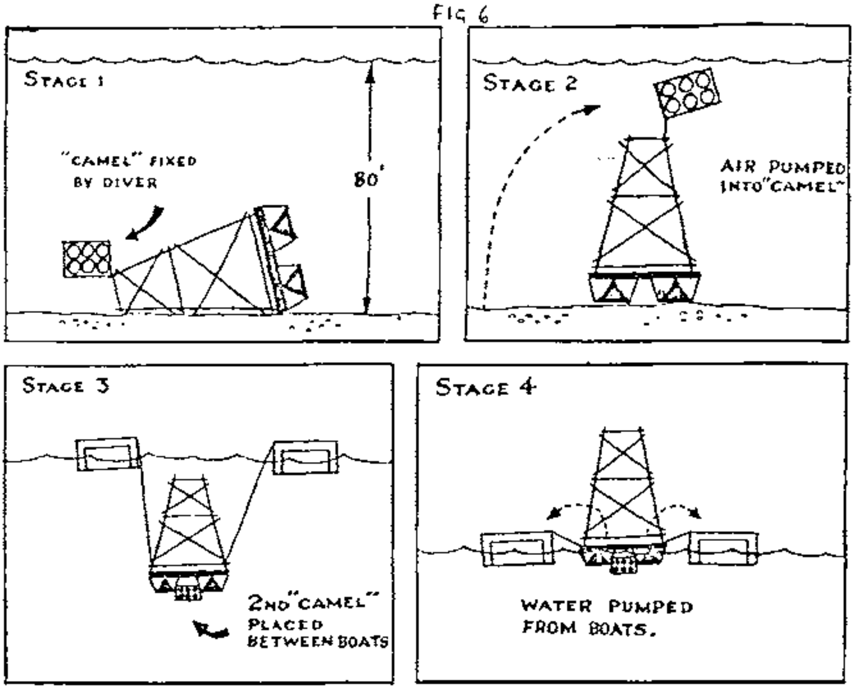
Salvage operations were resumed at first light on Friday, 27th June and, with the aid of a motor tug each for the Bailey rafts and an Evinrude powered stormboat for the F.B.E. raft, all three contraptions were pushed along their respective wires towards the wreck. As had been hoped this rose to within a few feet of the surface, but not unnaturally, lying on its side with its tower horizontal. The three salvage craft were now choc-a-block and no further lift could be obtained in this way. A spare F.B.E. raft complete with tower was then brought in to form the fourth side of the square (Fig. 7), and a winch and tackle fitted so that the pull came from the top of the floating tower to the top of the sunken one. In this way the tower of the wreck was raised inch by inch throughout the day, until at 9.30 p.m. it was two-thirds clear of the water, though still at an angle of 45 deg. Winching had been slow, as continual reinforcing of the winch tower had to be carried out as tubular members in succession showed signs of failure.

An attempt was made to sink "Camels" made of 40-gallon drums into the uppermost boat, and then to blow them out with compressed air from the Pescara mounted on an F.B.E. raft. This was not successful, as the continual wind and rain made underwater visibility very bad and it was not possible to position the barrels so that the bung-hole stayed downwards. Although this initial attempt at using camels had failed, it was quite clearly impossible to lift the wreck the last few feet by brute force alone, as the salvage tower and the winch lines were creaking ominously. It was therefore decided to take the camels rather more seriously, and during the night a wooden crate was built to hold four drums in such a way that the completed article would fit underneath the roadbearers between the two boats. Thanks entirely to the sheer guts and perseverance of three volunteer divers, 2nd Lieutenant Mike Weeden and Sappers Maloney and Green, the camel was correctly positioned between the boats first thing the next morning. Pushing a cumbersome crate beneath the water and wrestling with a compressed air hose to get the end of it into four bung-holes in succession at a depth of 15 ft. was neither easy nor enjoyable. The fact that it was carried out with such success and enthusiasm could perhaps be attributed to the firm determination of all ranks to get at least one raft up before the naval experts arrived.

The naval diving party from H.M.S. *Vernon* arrived on the evening of Sunday, 29th June, and immediately carried out a surface reconnaissance of the lake and the salvage craft already in use. In view of the success already achieved with the first wreck it was agreed that the same drill should be continued, the divers being used to attach the camel to the top of the sunken tower whilst the wreck was still on the mud. (Fig. 6.)

The salvage craft had been positioned over the second wreck on Sunday, and early on Monday morning the divers took the original four drum camel down and connected the winch wires from the Bailey rafts directly to the road-bearers of the wreck. The drums were then blown, which brought the tower upright, and by taking in all four winch wires simultaneously the wreck was raised to a position where the top of the tower was just breaking the surface. As it was still too much of a strain to lift the wreck completely out of the water, a second and larger camel of six drums was slipped between the sunken boats. When blown it raised the wreck sufficiently for the gunwales of the boats to break surface. No. 5 pumping sets were then put to work and the boats pumped dry. Surprisingly enough, except for a few missing deck panels, the raft and tower was almost completely undamaged.

In the subsequent salvage of the remaining three wrecks, the Navy substituted special self-inflating rubber bags for the rather cumbersome oil drum camels and work was speeded up considerably, although the drill, FIG 6


STAGE 1
"CAMEL" FIXED BY DIVER
80'
STAGE 2
AIR PUMPED INTO "CAMEL"
STAGE 3
2ND "CAMEL" PLACED BETWEEN BOATS
STAGE 4
WATER PUMPED FROM BOATS.

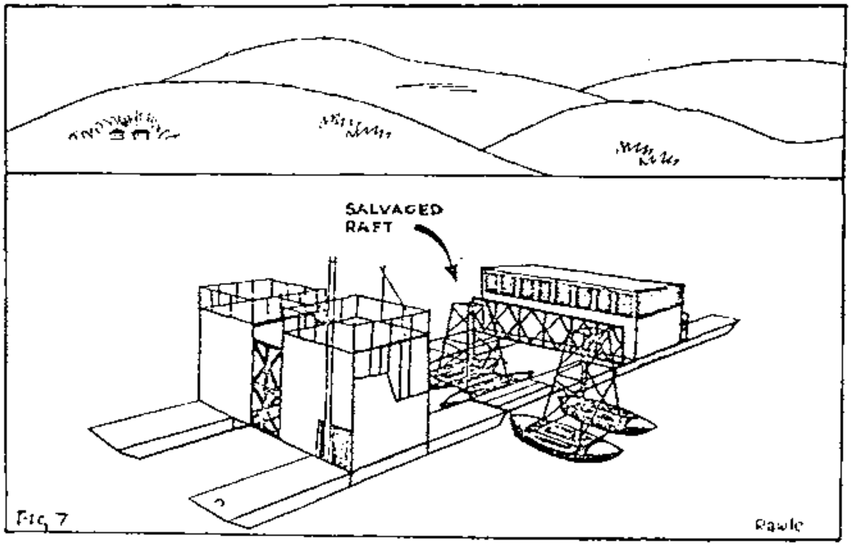

SALVAGED RAFT
Rawle

FIG 7

already well proved, remained the same. The buoyancy bags were taken down whilst deflated and, after being fixed to the wreck, were blown up by the diver by opening a valve on the built-in air bottles. Two bags were fitted at a time, each with a lift of about a thousand pounds. As soon as the bags broke surface, the winch brakes were applied and the bags were removed, deflated and repositioned beneath the roadbearers of the wreck for a final lift.

In this way the wrecks were recovered at the rate of one a day, the course being rehabilitated simultaneously with the salvage work, with the result that by 4th July, the original deadline, it was once more ready for the crews to start practising.

Mention should be made here of the invaluable assistance given by Sub-Lieutenant Smith, R.N., and his naval divers who worked long hours under very trying conditions and, at a depth of 80 ft., in almost total darkness. The standard of what might be called their "underwater field engineering" (though doubtless the Navy have a name for it) was extremely high, and even the sappers were impressed by seeing bowlines on bights appearing from the depths.

The Races

Of the period between 5th–19th July, little need be said except that nature was kind and with the arrival and subsequent erection of the coloured overhead markers, the course became prettier every day. As the Press were fair to record, the crews thought highly of the course and indeed of the Army organization which provided for starting parties, launch crews, rescue teams and radio communications. It is therefore all the more ironic that nature should play her last ace on the last and Royal day of the Games.

The morning of 24th June broke fair with a gentle breeze from the northwest. The daily inspection of the course had revealed no hazards and all ranks went to an early lunch with an air of confidence and subdued excitement. At noon the breeze began to freshen, and although not strong enough to cause alarm, it was the first time in six weeks that the wind was not from the prevailing direction. A final tour of the course by the O.C. whilst the men were at lunch again proved everything to be as buoyant and shipshape as the day deserved, though the waves, accentuated by the 2-mile free run of the lake were making the folding boats buck to their cables. The Press and Judges' rafts, although of necessity anchored broadside on to the waves, were unmoved by their poppling, and nudged them back the way they had come, with only an occasional spume of spray to hint of what was in store.

It was, therefore, only as a safety precaution that the Squadron was ordered to its positions at 1 p.m. instead of at 2 p.m. to find as had been expected that all craft were riding high and dry. The wind, however, continued to freshen and by 2.15 p.m. one wave in every six was breaking over the deck of the upwind pontoon of the Judges' raft. Fred Beringer, in command of this raft, opened one of the hatches between waves and found that the upwind pontoon had taken on a couple of inches of water, but the effect on the overall buoyancy was negligible and in no way jusified the risk that would have been occasioned by keeping the hatches open to bail or pump out.

The first race had by this time started and although distinctly troubled by the waves that this almost gale force wind was bowling down the lake, the eights managed to complete the course with nothing worse than spray drenched clothes. The Judges' raft on the other hand was not faring so well and it was becoming apparent to Fred Beringer and his O.C., who had joined him on board, that the waves, which were now sweeping across the decks every few seconds, were seeping through somewhere. By raising one of the covers slightly it could be seen that the level of water in the offending bow section had risen 6 in., and a sapper was ordered to start bailing with a bucket. It was immediately obvious that more water was coming into the pontoon through the open hatch than was being thrown out, and it was decided that the only hope of keeping the raft afloat was to keep the hatches closed and pray that the races would end before the pontoon lost all its buoyancy. The remaining five pontoon sections of the raft were fortunately not taking in water and it was with a certain degree of confidence that the Judges and B.B.C. technicians on board were assured that they were in no danger. A No. 5 pumping set was brought aboard but was not initially used as there was no way of getting the suction hose into the hull without opening a hatch to the mercy of the over-riding waves.

During the third race the Duke of Edinburgh from his seat in the Royal box opposite the finish line noticed through his binoculars that the raft was beginning to list and remarked that it appeared to be in difficulties. Not unnaturally, those on the raft had realized that too, although there was nothing that could usefully be done about it. In desperation, and rather to be doing something than to stand idle in the face of disaster, the pumping set was started up and the hose thrust into the hull through the smallest hole that could be made by opening the hatch cover. But even this was too much and with a last despairing gurgle the upwind pontoon nosed its bow section beneath the surface, slowly but remorselessly surely.

In spite of the fact that the next race had just started it was decided without much hesitation that not a lot of faith could be pinned on the buoyancy of the remaining five pontoon sections; the remaining two upwind ones already being dragged gently but firmly beneath the surface, protesting the while with bursts of bubbles from the edges of so-called watertight hatch covers.

The order to abandon ship was obeyed rapidly and efficiently, and in the space of five minutes all the costly technical equipment belonging to the B.B.C. and Omega had been transferred to the catwalk. The Judges had meanwhile moved to the Press raft to sight through to the finish line for the race that was now within seconds of ending—unfortunately without the accompaniment of the B.B.C. commentary as all their circuits had had to be cut in the evacuation.

All faith in the watertightness of the remaining pontoons had by now vanished and it was only the immediate acquisition of some form of extra buoyancy that could prevent the whole raft from foundering in 90 ft. of water. This was available in the shape of a spare bow and centre section, but they were unfortunately at the other side of the lake and at that moment being used as a spectators quay at the hard. There was an additional obstacle in the fact that the brief from the Rowing Committee had clearly stipulated that the races could only be stopped or interfered with if it was a matter of saving life. Nevertheless, thanks to the very able watermanship of Sergeant Cooper and the tug operator, these spare sections were towed across at full speed, arriving alongside the raft just as the last race started. The raft had by this time listed to the point where the bottom chord of one panel was under water and it was only by getting several sappers very wet was it possible to lash the spare sections alongside, handrail to handrail. The raft continued to sink with the reserve sections taking more of the strain every moment until, by the end of the last race, it had reached a state of stable equilibrium with the deck at an angle of 45 deg.

The subsequent recovery of this raft was achieved without incident after the crowds had departed by bringing the Press raft alongside and lifting up the waterlogged pontoon with pull lift jacks. When the hatch covers broke surface two No. 5 pumping sets took over and completed the salvage operation. It should be added that the wind died shortly after the last race and by the time the pumping operations were started the water was once more dead calm.

Conclusion

When the raft was brought ashore the next day, it was found to be quite undamaged. On getting inside the bow section in question and closing down the hatches, a thin chink of light round the edges of the hatch covers, not more than an eighth of an inch wide, showed only too clearly how the waves had got in.

But who would have thought of standing two sappers on the top of every hatch cover as a preventive for shipwreck?

Training

By Lieut.-Colonel R. L. France, M.C., R.E.

Introduction

One of the most striking things about the young British Soldier is his desire to do an interesting and worthwhile job, particularly if there is a challenge to meet or an element of danger in doing it. I set down some brief thoughts on training and some training methods which exploit this quality. Most of these are well known but a summary may be useful now that we are beginning to recast our training programmes to fit the new regular army.

Conditions in this army will be different in that we shall no longer be training Sappers on a short term basis, and in the present unsettled world conditions there will be a need to train them to operate in more varying conditions—to be more ubiquitous than ever before.

This latter need should quicken interest in training by the variety and evident purpose of the tasks to be done. If we can also make training imaginative and exciting the morale of our units should be high, and there should be no difficulty in attracting the enterprising and energetic type of recruit we need in the Sappers of the future.

Basic Individual Training

Whether basic individual training be carried out in the Junior Leaders Regiment, Apprentice Units or in a Training Regiment much of the initial training must largely consist of P.T., education and drill. Trade training should follow together with training of the Commando or "Outward Bound" type. Some comments are made under these headings below.

(*a*) *Physical Training*

There must be plenty of P.T. in the early days with the aim of correcting physical weaknesses and building up strength so that other forms of strenuous training can follow. Variety and interest can be achieved by introducing games and competitions in which all must take part. A challenge can later be added by assault P.T. courses which can easily be improvised in most localities. Successful completion of such a course gives useful simple lessons in team work and leadership as well as giving a sense of achievement.

(*b*) *Drill*

Drill is essential for inculcating smartness, alertness and soldierly pride in the individual and in his unit. At the basic training stage the movements to be learnt must be few, simple and must be well done. At this period in order to improve the standard it is acceptable to practice moving to all tasks in formed bodies under N.C.Os. or selected sappers.

(*c*) *Education*

The period of basic training is the time to concentrate on education, which in field units is often squeezed out by other pressing needs. Subjects can be made more interesting if they are both practical and topical. In particular map reading, combined with simple cross country marches, is always popular if well organized. History and geography should be related to likely campaigning areas, and Officers and N.C.Os. of the unit who have personal experience of the area are always heard with interest. Technical drawing is a practical subject and good to take from the Corps point of view.

In the Junior Leaders Regiment and in Apprentice Schools there is great opportunity to study, and with the better standard of boy becoming available the majority should gain their Senior Certificate of Education, which is of slightly higher standard than the Army First Class Certificate.

(*d*) *Weapon training*

Weapon training in the Corps has suffered through lack of time and the need to train National Servicemen in other subjects. Many more vacancies must be taken up at the Small Arms School, Hythe, before our regular element can be brought up to standard. When individuals are more proficient units should take on field firing practices to introduce realism and interest.

(*e*) *Field engineering*

With the increasing time which may be devoted to this subject by recruits and ex-apprentices at the Training Regiments there seems no reason why a good third class standard should not be reached by all. It will be important to consolidate this by early experience in a field unit when a second class standard should be achieved by many at the end of the first full training season.

In the case of the Junior Leaders' Regiment all F.E. subjects except bridging are covered, although improvised rafting and watermanship are now included in "Outward Bound" training.

There is much to be said for qualifying all drivers in regular field units up to F.E. B.III standard, when it becomes possible to devote the necessary time. They can then take their place intelligently in sapper working parties in times of stress.

(f) Trade Training

It is of great importance to recruiting to be able to offer the incentive of learning a civilian trade which is also a qualification for a "complete" sapper. But it is difficult to see trade training being fitted into recruit training, and there is much to be said for giving the majority of field engineers a chance to get their second class trade rating before diverting them on to trade training. In this period the prospective N.C.O. will usually blossom forth.

The ex-apprentice will already have his trade on joining a training regiment and it is to be hoped that an increasing number of Sapper Junior Leaders, by using some of their evening hobby time to gain experience, will reach a third class standard in the following trades which they are now being taught: carpenter, painter, bricklayer, fitter (I.C. and P.), welder, technical drawing (towards draughtsman trade).

(g) "Outward bound" training

This type of training should begin just as soon as the recruit, young junior leader or apprentice has been physically hardened to get the full benefit of it. "Outward bound" training will develop individual character, initiative, self reliance and determination and will teach a man to take his part in a small team. He will need all these qualities in future wars where discipline, loss of control, cross country mobility and speed of action will loom more important than in the past. Moreover, it brings the leader (sometimes an unexpected one) quickly to the fore and gives him excellent practice in leadership.

Lack of time prevents "Outward Bound" training being included in the present recruit training programme, but it is now being given greater emphasis in the Sapper Junior Leaders' Regiment. In the Apprentice Schools it also receives attention and vacancies are taken on the Army "Outward Bound" school courses. Great interest can be created by this type of training. For example, a party of Sappers can be split into small groups and given an objective which entails a strenuous cross country journey in which they have to find their way by map, carry their rations and camping kit, and cross an obstacle which demands some initiative. The maximum amount of detailed organization and planning should be left to individual groups, who will enjoy doing it. All sorts of variations of this type of training can be thought up and graded in difficulty. Associated training in first aid, simple fieldcraft and improvised rafting can be added as time permits.

(h) Leadership training

There is no better way of developing leadership than by giving responsibility to likely young men and boys. The task given must be suited to their capability. Many tasks, such as taking charge of a small party, as described in the last paragraph, require little previous instruction and yet will demand organizing ability, power of decision, resourcefulness and determination to some degree. Many lessons will be learnt the hard way but they will be well learnt, particularly if instructors can be made available to watch progress.

Opportunity must be sought to give responsibility to young leaders in every phase of barrack life as well as training. There are many simple ways of doing this and self confidence will not be developed quickly if these opportunities are missed.

In addition to the training mentioned above, instruction must be given to all junior leaders and prospective N.C.Os. on N.C.O. duties, discipline, etc.

Another aspect of leadership training which needs more positive action is man-management. Leaders, both Officers and N.C.Os., are given little direct instruction in this subject. Admittedly experience and commonsense count a great deal but I am sure we should avoid many of the examples of poor man-management we see if more time could be devoted specially to this subject in training programmes for Officers as well as N.C.Os.

Unit Training

An annual training cycle is very desirable and enables training to be progressive from the individual to the sub-unit and then to the unit, the unit eventually exercising with all arms, first by signal exercise and then full-scale exercise. If all is planned well in advance postings, leave and courses etc., can be planned to the best advantage and training equipment distributed equitably. Some comments on the various phases follow.

(*a*) *Individual training*

Individual training will be devoted to improving individual skills and, as this will mean a good deal of revision in the all regular army, changes should be rung and realism introduced wherever possible. As Sappers we are well able to do this by the variety and nature of our equipment and tasks. There is a tendency to decentralize individual training and some ingenuity and effort will be required to keep it "alive". As mentioned already "Outward Bound" training is a good way of doing this and should be introduced as a variation whenever possible.

Many men will wish to improve their civilian trade qualification to a standard acceptable by trade unions and opportunity must be given to them to do so.

(*b*) *Sub-unit training*

Sub-unit training at the troop level is by far the most important part of the cycle. The sub-unit "team" is rewelded each year to fit the newcomers into their places. It gives the best opportunity to all ranks to exercise their roles in the teams, including the administrative section. It is, therefore, most important to introduce realism and variety.

The sub-unit should be given every opportunity to get out of barracks and every help to train on suitable ground. At this level this would not be difficult if a good liaison is developed with local landowners. Though out of phase in the training cycle the sub-unit should go out occasionally in the winter months.

As stated in a recent article in this *Journal*, Sappers are more likely to have to defend themselves and move tactically on foot in any future war. Simple infantry tactical exercises and "Outward Bound" exercises at the sub-unit level should be arranged, taking advantage of rivers or mountains within reach for river passages, mountain training, ski-ing in winter, etc. Such exercises will be found to be very popular and are a good pipe-opener for schemes with a more Sapper bias. Night schemes should be included occasionally and inter-troop competitions introduced where practicable. In all these exercises a liberal supply of training aids such as blank ammunition and trip flares will help.

With training time becoming more plentiful than at present it should be possible for the sub-unit to tackle the small works project occasionally.

(c) *Unit training*

Unit training exercises should be held less frequently but often enough to give the sub-units a sense of interdependence and team spirit at a higher level. Signal exercises will practise the unit H.Q., particularly if conducted with other arms. If the unit is left in any station for a considerable time the changes may be rung by practising for roles in different parts of the world where the emphasis changes.

This brings me to the increasingly difficult problem of holding full scale all arms exercises in this or any well roaded country. There is much to be said for carrying out such training overseas, particularly in Commonwealth countries, where there is more freedom of movement. The attraction of such moves on a short term basis are very manifest. As the Army becomes more air transportable this may well come to be possible if heavy equipment can be left on site for successive formations.

Overseas works projects like the present work on Christmas Island can offer invaluable training and it is to be hoped that opportunities such as this will continue.

On the question of courses outside the unit, there should be more time to devote to training unit personnel in all aspects of training except where lack of qualified instructors or special equipment precludes doing this internally.

Finally, the question of ceremonial parades. These are an excellent tonic to morale if they are kept to one or two a year and they are simple in form so that they can be well done without excessive preparation.

Conclusion

The standard of training of Sappers should rise when we are able to capture their interest and imagination by making training purposeful, varied and tinged with adventure.

Memoirs

LIEUT.-GENERAL SIR GIFFARD LE Q. MARTEL, K.C.B., K.B.E., D.S.O., M.C.

Lieut.-General Sir Giffard Martel was born on 10th October, 1889, the son of Major-General Sir Charles Martel, late R.A.

In 1903 he went to Wellington and won the Wellesley Scholarship which was awarded to the top boy on the modern side. Martel was very keen on games and boxed. He won his house colours for rugby football and represented Wellington College in the pair for the public school gymnastics.

At the Royal Military Academy he won his weight in boxing against Sandhurst and led a successful team of gymnasts. Martel passed out of Woolwich the head of his term.

He was commissioned in the Royal Engineers in July, 1909. During his two years at the S.M.E. he took up boxing seriously. He joined a club in the East End of London and boxed regularly to gain experience. He fought against all sorts, professionals and toughs of all descriptions. Frequently he was knocked out, but he became a first-class boxer as a result of his courage and determination in a hard school. He won the Army and inter-services Championship many times.

At the end of his time at Chatham, Martel was selected for an electrical and mechanical course and "served his time" in the North Eastern Railway shops at Darlington, living and working as a workman. He boxed with the men and no doubt made many friends he was later to meet when he commanded the 50th (Northumbrian) Division. Martel often remarked how valuable was this mechanical engineering training to him afterwards.

He was posted to the 9th Field Company and embarked for the First World War with the 4th Division. Two years later after a brief period, as Brigade Major of an Infantry Brigade, he was moved to a similar appointment with the newly formed Tank Brigade. His connexion with tanks continued from that time until the end of his service when he commanded the Armoured Corps in the Second World War.

After the 1914–18 War he was posted to the Experimental Bridging Establishment. An officer who served with him writes: "The unit had got a little down, but the impact of the arrival of 'Q' on the Company was electric and all lethargy soon disappeared. 'Q' was full of infectious enthusiasm and the unit improved rapidly. Training was made most interesting and 'Q's' inventive genius and technical skill produced bridges and Sapper gadgets of all natures required for the needs of a modern mechanical Army." He also designed tracked vehicles to assist in engineering work. He did much preliminary work which led to the development of the Bailey Bridge and for his services and his inventions he was awarded a substantial sum by the Government, the whole of which he presented to the R.E. Benevolent Fund.

After a course at the Staff College he returned to regimental duty and commanded the first mechanized Field Company in the Experimental Mechanized Brigade. Later he was posted to the War Office and it was during this time that he designed and constructed with his own hands in his own workshop at his house the Martel light tank, the first of its kind. This tank produced general interest in the Army and became the forerunner of the light tank and the Infantry machine-gun carrier.

Leiut General Sir Giffard Le Q Martel KCB KBE DSO MC

He was posted to India in 1928 and for a period was with the Bengal Sappers and Miners. He was appointed an instructor at the Staff College, Quetta. An officer who served under him writes: " 'Q' was immensely popular and stimulating as an instructor and was always full of ideas. He was a keen follower of the Quetta hunt and played polo. He had no eye for a ball and took up Shikar instead; spending his leave in the hills after Markhor and in the jungle after tiger. He was very successful and secured some good specimens."

After a course at the Imperial Defence College and a short period at the War Office, he was appointed in 1939 G.O.C. 50th Division, which he took to France in 1940. The frequent favourable reference to Martel in Lord Alanbrook's Diaries *The Turn of the Tide,* indicate his success as a Divisional Commander in war.

On returning to England he was appointed Commander Royal Armoured Corps, his main responsibility being to raise a large number of armoured units and to train these on a common doctrine. As was to be expected there was a marked divergence of opinion on the problems of armoured warfare and of the types of tanks and organization that was required. Martel's success in obtaining general agreement without friction was a tribute to his character and reputation.

In 1943 he was selected to be the head of the British Military Mission to Russia. Relations with the Russians were by no means easy but in time Martel, by his fearless outspokenness and determination established as good relations with them as was possible and without doubt gained their respect.

Martel lost an eye as a result of a bomb on the Army and Navy Club in London and this virtually terminated his active military career.

On his retirement in 1944, he became active in many spheres in civil life. He was Chairman of the Royal Cancer Hospital and unsuccessfully contested as a Conservative in the Barnard Castle Division of Durham. Here he had the support of many of the men of his old Division, but the odds against him were heavy.

Martel joined the Army in the horse age and lived to see great scientific and mechanical developments in all branches of the Army and the introduction of the atom bomb. As his record shows, Martel played an important part in these developments. In the past it has been given to few senior officers to possess such a wide tactical and technical knowledge and experience such as his.

Q. Martel was a good sportsman and a loyal friend; a strong character and fearless morally and physically. He was outspoken in expressing his views and in stating what he thought was right—in doing so, he gave no thought to his own interests.

Devoted to his family he was very happy in his home life. Universally respected, Q. Martel was an outstanding Sapper and his heart was in the Corps.

It was a splendid final honour and tribute to "Q" that Her Majesty the Queen should express the wish to be represented at his Memorial Service at the Chapel at the Royal Military Academy on the 15th October, 1958.

A.E.G.

BRIGADIER-GENERAL G. R. FRITH, C.B., C.M.G., D.S.O.

Gilbert Robertson Frith was born in September 1873 at Halifax in Canada. He was educated at the Upper Canada College and afterwards at the R.M.C. Kingston, Canada, where he was awarded the Gold Medal for his term.

In June, 1895, he was commissioned in the Royal Engineers and then completed the normal training course at Chatham.

Shortly afterwards he was selected for a railway course and was attached to the Midland Railway. In 1899 he was sent to South Africa and served with the 8th (Railway) Company throughout this war. His energy and efficient conduct earned him a Mention in Despatches.

Soon after this war he was appointed Assistant Commissioner, Anglo-French Boundary Commission in Nigeria, with the temporary rank of Captain. He took part in the Kana Sokoto Campaign of 1903, and left Nigeria the next year.

From 1904 till January, 1909, he remained at the War Office as a Staff Captain and then as a G.S.O.3 in the Military Operations branch, and afterwards passed through the Staff College, Camberley.

In 1911 he commanded a Railway Company at Longmoor for a few months

Brigadier General GR Frith CB CMG DSO

before returning to the War Office, first as D.A.A.G. and then as A.A.G. in 1915. His outstanding energy and efficient work were recognized by the grant of a Brevet Majority in 1913, followed by a Brevet Lieut.-Colonelcy in 1915.

In July 1915 he was appointed A.A. & Q.M.G. Canadian Corps, Expeditionary Force, and won the D.S.O. in 1916 and a Brevet Colonelcy in January 1917. To have received three brevets in four years is no mean feat, and a fine tribute to Frith's ability.

In March 1917 he became D.A. & Q.M.G. XV Corps and a Brigadier-General, and was awarded the C.M.G. in 1918 for his excellent work. In July 1919 he was appointed D.A. & Q.M.G. of IV Corps, then of II Corps for a few months, until in 1920 he became Deputy Chief Engineer, Eastern Command.

The next two years Frith spent in Mesopotamia (Iraq), as Brigadier i/c. Administration, for which he was decorated with the C.B. He then returned to the United Kingdom and remained on half pay until his retirement in October 1923.

Brigadier-General Frith was an exceptionally able and energetic administrative staff officer, who gained many honours. In addition to those already recorded, he received a share of Mentions in Despatches during the First World War, and was made an Officier, Legion d'Honneur and received the French Croix de Guerre. He was also made a Commandeur, Mérite d'Agricole.

He had a very active mind which remained keen and clear until his death at the age of 85 years on 6th October 1958.

He married in 1916 Olive Fergusson, who, with one daughter, survive him.

COLONEL C. E. HOWARD-VYSE, O.B.E.

CECIL ELSMIE HOWARD-VYSE, who died on 23rd September at his home, Langton, near Malton, Yorkshire, after a long illness, was born in February 1901, the elder son of Lieut.-Colonel (R.A.) and Mrs. C. Howard-Vyse.

After going to school at Wellington, he went to the Shop and was commissioned in July 1920. A two-year Chatham course was followed by the E.L. course at Gosport (he already showed pronounced E. & M. interests), and then, after a short time at Devonport he was posted to India. Here he was attached to the Bengal Sappers and Miners while acting as O.C. Defence Light Section at Karachi.

While in India he married Marguerite Graham, daughter of Mr. and Mrs. Charles Ferrier of Carnoustie. There were no children. They came home in 1930, and after a short time as a G.E. in London he took the long E. & M. course; then for about three years served in works appointments in Catterick, whence he was posted in 1936 as O.C.R.E. in Shanghai at the time of the emergency there. It was in Shanghai that he developed an ability to get the best and most willing service from all ranks under him, and to serve with great tact and loyalty, all those above him. In July 1938 he was awarded the M.B.E.

The war broke out soon after his return to this country, and in July, 1940, he was appointed S.O.R.E. 12 Corps. Next year he went to the S.M.E. Ripon, first as Assistant Instructor, then Chief Instructor E. & M. School till

Photograph when a Major

Colonel C. E. Howard-Vyse, O.B.E.

June 1943. In 1944 he was posted to 6 L. of C. Troops Engineers as a T/Lieut.-Colonel and served in North-West Europe. In 1945 he was appointed C.R.E. H.Q. E. & M. Units with 21 Army Group and later received the O.B.E. for his services in N.W. Europe.

After the war he became D.D.W. (E. & M.), and then D.D.E.S., at H.Q. B.A.O.R., and finally, in 1949, D.D.E.S. at the War Office.

He retired in December 1951.

It is difficult to express in a few words all that goes to constitute a personality but it was perhaps an unfailing sense of humour, carrying with it a

Colonel CE Howard Vyse OBE

natural sense of balance and proportion, and especially of fairness, that endeared him, as much as his other qualities, to all ranks who served with him.

After his retirement he lived very happily at home until he was taken ill in February 1957. It was the way in which he faced this adversity, in the last eighteen months of his life, which will always remain the admiration of those who were around him.

There will be many, of all ranks, in the Corps who will learn of his death with a real feeling of personal loss. J.F.F.

Correspondence

Brigadier Sir Mark C. A. Henniker, Bt.
C.B.E., D.S.O., M.C. (Retd.),
St. Christoph,
Baundstone,
Farnham, Surrey.

The Editor,
Royal Engineers Journal

Dear Sir,

A PERSONAL TRIBUTE TO THE LATE BRIGADIER C. C. PHIPPS, C.B.E., M.C.

May I add a personal tribute to the memory of Brigadier Phipps? The date was 23rd May, 1940. Belgium was about to capitulate, France was doomed to fall, encircling German forces were closing round the B.E.F., and the military picture in France was bleak in the extreme. Phipps was C.E. Second Corps, to which I had been posted as O.C. 253 Field Company, R.E., in the 3rd Division; so I went to see him on my way to my first command in war. He was sitting at a writing desk in the study of a *château* taken over as Corps H.Q. On the wall was a map and in front of it two chairs.

The C.E. must have had a good deal to do and certainly a load of responsibility to shoulder; but Phipps seemed to have plenty of time for me, a mere captain. We sat in front of the map; and he told me about the military situation, calmly working from the wide view, down to the actual tasks he supposed my field company would have to undertake in the next few days. It was a real tonic for one who had just come—as I had—through the streams of refugees, retreating formations and (regrettably) numerous deserters with their tales of woe. It showed that direction at the top had not wavered, and focused in my mind the things that mattered.

Finally, he pointed at a feature on the map across the river line the 3rd Division was holding. "You see that hill?" he said. "Well, I advise you to make sure that your Company H.Q. is not within sight of it. It looks from the map as though it might be. If it is, I'd move it, if I were you."

We shook hands, he wished me good luck, and we parted. Dick Walker, who was then Adjutant R.E., 3rd Division, motored me from H.Q., 3rd Division to 253 Field Company. As we approached, I watched the hill Phipps had spoken of appear in the distant country panorama; and as we got nearer to our destination it became more and more a dominating landmark.

Eventually we reached the farmhouse where the Company H.Q. was set. It was a Territorial Company and resentful of having a Regular O.C. Indeed, I overheard one of the subalterns address his companions "Christ!" he exclaimed, "a bloody regular!"

Nor did they love me more, because my first act was to move the H.Q. from its comfortable farm to where it was out of sight of Phipps' hill, in a much less luxurious abode. But their detestation of the "bloody Regular" was quickly replaced by wonder at his professional sagacity; for they saw the late H.Q. battered to pieces by German artillery fire within a few hours of our leaving it. This was a turning point in our small world. I had gained the trust of my company and we went on from strength to strength. But let no one forget that the corner was turned because the Chief Engineer had a grasp of soldiering and an understanding of men that made him a rare companion in times of trouble—and we had plenty of trouble in those days.

I look back on that minor occasion as a small but brilliant gem of military experience. It reflects two priceless lessons, which every officer who aspires to high rank in the Corps should strive to learn. Phipps knew them both; and I should like to feel that some young reader will see these lines, and try and learn those lessons in memory of Phipps. And, having learnt them, put them into practice as C. C. Phipps did.

Salute to his memory.

Yours faithfully,

M. C. A. Henniker.

The Editor,
Royal Engineers Journal

Engineer Branch,
H.Q. Western Command, Chester.
9th September, 1958.

Dear Sir,

Two articles in the September issue of the *R.E. Journal*, "Teach Yourself to be a Garrison Engineer" by Major D. E. Thackeray, R.E., and "Registration of Engineers" by Major D. M. R. Esson, R.E., prompt me to speculate on a question which must occupy the thoughts of many officers in the Corps in view of the imminent civilianization of Engineer Works Services, that is "Who are the gentlemen who will in future fill these Works Appointments?"

In order to look at this question perhaps the present "set up" should first be examined on a very broad basis. In my experience Works appointments at present can be divided into two main categories, Military Appointments and Civilian Appointments. These appointments may, generally speaking, be further broken down as follows:—

Military

(*a*) Officers who over the years have acquired considerable experience of W.D. procedure.

(*b*) Officers from other branches of the Corps who arrive at "Works" to gain experience, these officers automatically classify themselves into two distinct types, those who approach the job with keenness and integrity and those who look forward to a "cushy" job, are disappointed, and from then on look upon the appointment as an evil necessity.

Civil

(*a*) Professionally qualified civil servants attached to the War Department.

(*b*) A very large number of civilians who hold professional appointments, the majority of whom at some time or other held commissions in the Corps.

In all of the above categories, gentlemen are to be found who hold recognized professional qualifications as awarded by virtue of passing the examinations of the appropriate engineering institutions. A very large number are not so qualified.

The Corps itself, covering as it does, almost all aspects of engineering, has only in one section made the possession of the appropriate qualification an absolute minimum requirement, I refer to the List of Military Quantity Surveyors. Officers on this list are subject to a preferential rate of promotion as compared to the remainder of the Corps, i.e. two years to substantive captain and nine years to major as opposed to six and thirteen years respectively.

In taking this step, the Corps has, to my way of thinking, admitted the principle that a job is best done by the man professionally qualified in that line. If this principle is in fact admitted, is it not reasonable to carry it to its logical conclusion and agree that for each appointment in Works Services the possession of an appropriate professional qualification is a necessity? e.g. the "Planning Officer" should be an A.R.I.B.A. (preferably with a diploma in planning), E. and M. Officers, A.M.I.E.E., or A.M.I.Mech.E., etc. In the past, within the Corps officers holding these recognized qualifications have not been raised head and shoulders above officers not qualified, certainly not to the extent enjoyed by Q.S. officers. I cannot agree that their work is any less specialized than that of a quantity surveyor.

The Civil Service, in recruiting for its appointments with the War Department does recognize this principle and in its public advertisements states the qualification expected for the appointment. It is, however, a fact that in the past, difficulty has been experienced in recruiting qualified personnel, with the result that the requirements have been "relaxed" and unqualified persons have gratefully slipped in to appointments through the back door, usually in a temporary capacity. Just how "temporary" these appointments have been may be gauged from the fact that whereas the normal retiring age for civilians is 60 years, gentlemen in these appointments are often found to be not even 65 but 68 and 70.

Any attempt at querying the suitability of these unqualified persons is dismissed under the vague expression "Men of vast experience" and a direct approach to the individuals concerned as to why they have not qualified is met with "Too old to start studying at my age", little realizing that acknowledgment of the need for study is in itself admission of incomplete knowledge.

As stated in Major Esson's article, architects have by virtue of their Institute secured for themselves a reasonable measure of protection, this type of protection is also enjoyed by members of other professions. Doctors of medicine are not suddenly faced with competition from male and female nurses who have gained "vast experience" over the years. No British shipping firm will give command of their ships to men who do not hold a master's certificate.

In engineering, however, the situation is not so clear, especially in post-war years, almost every second man in the street now appears to be "an engineer". The local plumber has blossomed into "sanitary engineer", the motor mechanic has vanished and his place taken by "automobile engineer". The most ridiculous example which has come to my attention is that of a "watch and clock repairer" who now asserts he is a "mechanical engineer". The most amusing example surely is that of the old "Council rat-catcher" who now officially has the high sounding title of "rodent operator".

What then is the future of engineers, especially in regard to appointments in the new organization? Members of the great engineering bodies can do much to safeguard their status by bringing pressure to bear through their institutes and through the I.P.C.S. (Institution of Professional Civil Servants). It is not my contention that persons at present not professionally qualified are in all cases unsuitable for the job in hand but that in deciding merit professional qualifications are an accepted yardstick. Gentlemen who wish to obtain appointments should therefore be prepared to qualify, age is no barrier as is shown by the fact that almost every S.Q.S. (Lieut.-Colonel) on the present list of Military Quantity Surveyors, qualified at a later date in life than is usual. Most institutions cater for persons in this category by holding "direct membership examinations".

In closing may I say that there is considerably more to being a thoroughly competent Garrison Engineer than the mere ability to give "P.R.Es. off the cuff" and keeping C.Os. of units happy by "advising" troops on how to slap on paint. Advice on paint treatments is in itself so specialized a subject that paint manufacturers employ their own research chemists to advise them.

It is to be hoped therefore that the watchword of the new civilian works services organization will be based on the criterion of the "right man for the job" and not on the necessity of finding "jobs for the boys of the old brigade".

Yours faithfully,

D. I. C. JONES, Captain, R.E.

Editorial Note. A survey of the May, 1958, *R.E. List* indicates that forty-one serving members of the Corps are M.I.C.E., or A.M.I.C.E. It is understood that it is the Engineer-in-Chief's intention that in future many more should so qualify.

H.Q. S.W. District,
Sherford Camp, Taunton.
16th September, 1958.

The Editor,
Royal Engineers Journal.

Dear Sir,

I should like to make one point concerning Lieut.-Colonel Montrésor's excellent article on "Trade Training" in the September issue. In the heading quotation I consider even more important than training are the words "and practice". Very many good tradesmen, potential recruits for the Corps, are lost because we do not guarantee practice at their trades. In fact some recruiting literature does, somewhat dishonestly, imply that trade practice is available.

I suggest that it is *essential* for every tradesman in the Corps to work three to four months annually at his trade. This could surely be an inflexible rule with a regular army and in co-operation with Engineer Services.

When I was a Subaltern my Field Company had a winter task of constructing a small building complete. Survey, laying out, quantities, ordering stores etc., were all included. This was excellent training at all levels. It also produced a cheap building which I am told is still in use!

Yours faithfully,

R. T. Weld, Colonel.

The Editor,
Royal Engineers Journal.

Chief Engineer,
Gibraltar.

Dear Sir,

Captain Aylwin-Foster's article on Non Destructive Military Applications of Nuclear Energy in the June *R.E. Journal* has been read with great interest. There are, however, several rather inaccurate references to Gibraltar, most of which are minor and are not worth comment.

There is one which calls for comment and that is on the cost of electricity. The cost of electricity quoted as 3½d. per unit sent out is extremely misleading. The overall cost is now in any case down to 2.8d. Of this the fuel and labour costs per unit generated are only 1.3: the remainder of the cost is made up of distribution charges, station load depreciation, interest on capital, rates, and all the other bits and bobs which the costings experts delight to add in.

It should also be borne in mind that a power station, in a location dictated by military, rather than technical factors, and set in an area where fresh water is very scarce can hardly hope to compete financially with ordinary commercial generating stations.

Yours faithfully,

C. R. Nicholls, M.B.E., Colonel.

C.R.E. South Wales,
Station Road,
Abergavenny,
Monmouthshire.
18th September, 1958.

The Editor,
Royal Engineers Journal

Dear Sir,

I crave your indulgence to add just one more letter to the recent correspondence on "Armoured" (at last, thank goodness!) Engineers.

First, I would like to add weight to Major Goodall's remarks on crew training in the March 1958 edition of the *Journal*.

Based on my experience during the war of using sappers to operate and maintain Valentine bridge-layers, and also my peacetime experience when commanding an assault regiment, I consider that individual crew members, whether it be driver, signaller or gunner, can easily be trained to carry out those individual tasks in a matter of a few weeks. To train individuals to work as a crew who would be able to obtain the best use out of their equipment under battle conditions, and above all to train A.V.R.E. Commanders, is a very much longer and more difficult task.

Secondly, Lieut.-Colonel France, in his letter in the September 1958 issue, refers to the necessity for all field squadron officers to know more about A.Vs., R.E.

I would go further than this. I would say that all N.C.O. as well as officer engineer courses at Chatham should give as much weight to instruction in the capabilities and uses of A.Vs., R.E. and their weapons, ARKs etc. as they do to conventional bridges, demolition charges and earthmoving plant. I am a little out of touch with courses at the S.M.E. at present, and I may therefore be out of date with my remarks, in which case I apologize for wasting space.

Lastly, but by no means least, we must see that armoured engineers' equipment has its proper place in the various pocket books. As far as I can trace, details of the equipment are not given in any printed publication. I consider that there should be an R.E.S.P.B. allotted to this equipment, or at least a chapter given in the appropriate existing pocket books, i.e. bridging, demolitions, earthmoving plant.

Yours faithfully,
B. G. Bloomer, Lieut.-Colonel, R.E.

Headquarters Task Force Grapple,
Air Ministry,
Whitehall Gardens, S.W.1.
6th November, 1958.

The Editor,
Royal Engineers Journal

GUNS OR JAM

Dear Sir,

May I prolong the discussion on Armoured Engineers? It would perhaps help if I quoted my authority for erupting into print on this subject.

I have twice been involved in Armoured Engineers. The first time was in Assam/Burma with 2nd Division, where with the co-operation of Cavalry and Tank Regiments we developed in early 1944 our own dozer tanks and A.Vs., R.E. (without petards). The second time was service with H.Q. 7th Armoured Division in 1956–7, when some of the new formations were exercised against a nuclear background.

The question of the Brigading of Armoured Engineers surely resolves itself into a question of what price can be paid to have Armoured Engineers in a brigade. If they are centralized at Corps they may never be deployed in time at the correct place. If they are brigaded more of them are needed and some of them may be idle. Bearing in mind the difficulty Lieut.-Colonel France had to redeploy in Italy, it seems likely that greater difficulties will pertain in nuclear war. In view of current doctrine it would appear that armoured brigades will be launched at short notice to destroy enemy forces. Although I have not put the question to an Armoured Regimental Commander I believe that it would be better to advance fast with thirty-six tanks than not to advance with forty-eight. It may be that the expense of creating Armoured Engineers could be alleviated by some reductions in tank strengths elsewhere. As regards waste, which in this case is also the price of readiness, will Armoured Engineers be inactive any more than was the reserve company of an infantry battalion, bearing in mind that requirements to hold ground as such will probably be reduced?

This problem of expensive equipment is one which must bedevil all future military thought. Self-propelled bridging equipment and amphibious are examples of other desirable equipments.

The A.P.C. problem is similar (see Major-General Hackett's article in *B.A.R.*, No. 7 of September 1958).

Moreover, I do believe that an army which enters nuclear conflict without Armoured Engineers, Infantry in A.P.C.s, and possibly some amphibians or self-propelled bridging equipment as an integral part of its armoured brigades will be at a serious disadvantage. The same sort of disadvantage that was resolved by the German advance in 1940. An equipment, and developing therefrom, a tactical disadvantage.

The following conclusions arise:—

(*a*) That the Armoured Engineers must live and train with the formation they are to work with in war.

(*b*) Arising from this, their basic equipment must be maintained in the formation workshop. It must therefore be based on the current tank chassis and workshops must be scaled appropriately.

(*c*) That the above conclusions hold good for A.P.C.s.

(*d*) Under the existing organization a small number of amphibians and a supply of self-propelled bridging equipment may be acceptable at Corps.

Yours faithfully,

G. Andrews-Speed, Major, R.E.

Editorial Note

This subject was discussed at the Engineer-in-Chief's Conference held at the S.M.E. in November this year. In consequence it has been decided to include more instruction in the capabilities and use of armoured engineers in all officers' courses, including Y.O.'s and J.O.'s, given by the Tactical School, and in F.E. (B1) and F.E. instructors courses for W.O.'s and N.C.O.'s run by the Field Engineering School at the S.M.E. Considerations of time, manpower and equipment, however, make it unlikely that it will be possible to give practical instruction in the operation of armoured engineer equipment at Chatham.

Book Reviews

UNEXPLODED BOMB. THE STORY OF BOMB DISPOSAL

By MAJOR HARTLEY, M.B.E., R.E.

(Published by Cassell & Co. Ltd. Price 21s.)

Owing to the need for concealing from the enemy our progress in the art of dealing with unexploded bombs a strict censorship was in force for most of the war and very little information has been published on the subject, with the result that there was a danger that lessons learnt from our experience of bomb disposal, and the outstanding achievements of those concerned, would be forgotten. This danger has been splendidly averted by the publication of this book.

The author, Major Hartley, has served sixteen years in Bomb Disposal and is still serving in it; he writes, therefore, from direct knowledge of the subject, and from personal acquaintance with many of the people engaged on the work and referred to in the narrative. He writes in a clear, straightforward style and has a pleasant sense of humour which helps to convey the atmosphere, particularly of the early days when bombs were many and knowledge and equipment, but never nerve, were lacking.

Bomb Disposal, which in its later stages included the V.I and V.II and minefield clearance, called for scientific research, technical skill, inventiveness and personal courage of a high order. All these aspects are well brought out by the author who strikes the right balance between the technical and human sides of the story.

In an introductory chapter he traces the early history of bombing from the air and describes, not without irony, the initial unpreparedness of this country to meet the danger of the unexploded bomb and the lack of co-operation between the Home Office and the Service Ministries. The events leading up to the decision to make the War Office responsible, in general, for the disposal of unexploded bombs are summarized, and the formation of the Unexploded Bombs Committee under the Ministry of Supply, and of the first Bomb Disposal Sections Royal Engineers which took place at the same time, are shown to have laid the foundation of the organization which carried on successfully throughout the war.

A clear description is given of the essential features of the German bombs and their fusing arrangements which is sufficient to make the subsequent account of the actions of all concerned with bomb disposal intelligible. The main theme of the book, however, is the growth of the Bomb Disposal organization in strength, technical knowledge and efficiency throughout the war. This is in the main the story of how, as new fuses, anti-handling devices and fresh weapons, the V.I and V.II, appeared, the necessary techniques and equipments were devised and brought into use. Since these techniques and equipments depended on accurate knowledge of the action of the various fuses and anti-handling devices, which could only be obtained from study of the device itself, much of the narrative consists of descriptions of the circumstances under which the first specimens came to hand. These accounts, and many others of the location and immunization of bombs presenting unusual features, are fascinating and bring a vivid picture to the reader's mind of the difficulties and dangers of the work and of the spirit of those engaged. It makes one understand the hold Bomb Disposal exerted on its devotees which was shown by the fact that hardly anyone exercised his option to transfer to other duties.

The book is strongly recommended to both the professional and general reader. It is of absorbing interest and, without indulging in any heroics, it pays a deserved tribute to a body of men who have enhanced the reputation of the Corps in carrying out a vital task in a spirit of dedication unfavoured by publicity.

A new age of nuclear explosives and long range weapons has arrived and, if we are to avoid the lack of preparedness which was responsible for so many casualties among Bomb Disposal personnel in the last war, the subject must be kept under constant review by all concerned with forming plans for action in the awful event of another. Apart, therefore, from its intrinsic value as a beautifully told story of gallant deeds it conveys a warning for the future.

J.S.W.S.

THE GENERALSHIP OF ALEXANDER THE GREAT

By MAJOR-GENERAL J. F. C. FULLER, C.B., C.B.E., D.S.O.

(Published by Messrs. Eyre & Spottiswoode, 1958. Price 35*s*.)

General Fuller became interested in Alexander the Great over forty years ago during the First World War. In 1923, as an innovation, he lectured on Alexander's campaigns to the students at Camberley, where he was an instructor. Now, in spirited defiance of the advance of old age, before which most men fade into silence and obscurity, he produces this fascinating single volume on Alexander's generalship. Indeed there is more to it than generalship, for the arts of kingship and government also come into the story.

For some of us, to whom the broad waters of the Jhelum were once familiar, the book will be a sad reminder of failure to investigate on the ground the famous battle of the Hydaspes. Full of ideas, we might have discussed its details with Sir Aurel Stein, who in our day was a familiar figure in officers' messes all over N.W. India and a man who rejoiced to sit at dinner surrounded by subalterns. Reading and re-reading the campaigns of the great captains, alas, was not a forte of young officers of that era. We could at least plead that, except for Plutarch, accounts of Alexander's battles were difficult to come by and we could contentedly remain in that sad state of ignorance, which is ever a barrier to human experience. With the General's latest book at his service, the aspirant to military fame has no longer any vestige of excuse for neglecting to read about Alexander. If he first reads Plutarch, he will discover from Fuller that modern critical study has modified former beliefs. The official historian Callisthenes, for instance, ceases to be a grave and worthy philosopher and emerges as a talkative busybody somewhat like our own Colonel Repington in the 1914–18 war. Callisthenes, in due course, was executed, not as a warning to official historians, but for conspiracy against Alexander.

Modern research also tones down the tradition that Alexander drank deeply with his generals for days together after a victory. Such an emendation seems ill to accord with the violence of his character, whereas recourse to the relaxation of an occasional drinking bout with boon companions admirably suits it. On this point, the reader will perhaps regret the industry of critical historians and will prefer Plutarch's livelier picture. The idiosyncrasies of great men should surely not be watered down.

General Fuller, for his part, goes out of his way to emphasize the quality of genius. Indeed to confront genius seems to ordinary mortals to be almost as hazardous as facing up to an advancing steam roller. Alexander the Great who "carried the power of life and death on the tip of his tongue" must often have petrified his entourage with anxiety and fear. Even so, the hero himself could never quite convince his Macedonians that the abject Persian salaam and other Persian court rituals were necessary adjuncts to his Kingship of Asia. In the end he had to accept their view and to treat the question as a matter which concerned only himself and the Persians. So even genius sometimes has to admit defeat. Undoubtedly the best part of the book is the smooth-flowing narrative with the description of the battles. The excellent sketch maps omit none of the place names and the diagrams are clarity itself. All this is admirable. But it seems an anti-climax to try and measure up Alexander's fiery generalship with the yardstick of the principles of war, as listed in obsolete Field

Service Regulations of the past. A descendant of Hercules does not lend himself to the strait waistcoat of mere principles. Nevertheless, as has been said above, this is a fascinating book. It was a happy thought to select as a frontispiece, a photograph of the profile of Alexander from a coin of Lysimachus (355–281 B.C.). A noble and heroic face!

B.T.W.

THE GYROSCOPE: THEORY AND APPLICATIONS

By JAMES B. SCARBOROUGH

(Published by Interscience Publishers Inc. Price $6.50.)

It sometimes happens that the best introduction to a subject is not given in a book exclusively dealing with that subject, and so it will be found in James B. Scarborough's book on the gyroscope. Besides the very thorough treatment on the subject of the gyroscope which it gives; it also provides a very useful introduction to vector methods in engineering science.

The clear exposition of the phenomenon of gyroscopic motion requires a knowledge of vector methods; but this need not deter the reader if he does not possess a knowledge of these methods, since the author covers all the groundwork required to follow the arguments at the beginning of the book. Simple applications of vector methods to problems in dynamics, leading up to the theory of the gyroscope then follow.

All the principle applications of the gyroscope from simple observable phenomenon, such as precessional effects on motor cars travelling around a curve, to the gyroscopic compass and stabilizer, are covered by a mathematical treatment which never exceeds the bounds of the framework laid down in the preliminary chapters.

The book can be recommended to the student of engineering who wishes to get an insight into vector methods by the application of these methods to real engineering problems. The more specialized theory of the stabilizer as used in ships may be left to those actively interested in the design of these components.

J.P.F.-S.

GEOLOGICAL STRUCTURES AND MAPS

By A. ROBERTS, M.Sc., Ph.D., A.M.I.Min.E.

(Published by Cleaver-Hume Press Ltd. Price 12s. 6d.)

The author has produced a very simple, clear and useful text-book which surveys the principles of interpretation of geological maps and includes graded exercises to practice the application of the principles. Supplementary chapters show some of the more important applications to civil engineering and to mine survey and working. For example, some of the problems connected with coal mining, oil drilling, building foundation problems, and water supply are touched on.

This is definitely a student's text-book. It gives, by means of very excellent diagrams, a complete introduction to geological maps. It is brief and concise, and makes no claim to be a manual on civil engineering. The inclusion of the chapters dealing with civil engineering problems do, however, indicate the real value of a science which might otherwise be considered merely academic.

T.W.T.

Technical Notes

Notes from *Civil Engineering and Public Works Review*, July, 1958.

Engineering Developments in the U.S.S.R.

A new technique for the erection of large tanks for the storage of oil, water or gas has been developed. Steel sheeting is seam welded to form a long continuous strip corresponding to the circular wall required. This is rolled up, as fabricated, like a roll of toilet paper, by which means it is easily transported to site. The wall is erected by standing the roll vertically on a flat bottom plate and unwinding it by means of a tractor winch, pegging it to shape by circular steel segments at top and bottom as the roll unwinds. A tank of 1.8 million $ft.^3$ capacity required a roll weighing 45 tons and was assembled employing six men, two tractors and a lifting "A" frame, in about five days.

Obtaining Samples of Cohesive Soils

An adaption of a "Cox" submarine bolt gun has now made it possible to take reasonably undisturbed samples from soft rock, clays, marls and silts without requiring a diamond drilling rig. The bolt gun is lowered into a borehole, and fired when it has reached the bottom. The specially designed sample tube is driven into the undisturbed rock or soil by the firing of the cartridge, after which both gun and sample tube can be hauled up to the surface.

Notes from *Civil Engineering and Public Works Review*, August, 1958.

Research on a New Doubly Curved Shell

This article is the first of three papers describing research work at the Central Building Research Institute, Roorkee, India. Shells in Nature are doubly curved and possess remarkable resistance to static and shock loads. To achieve similar results would be to economize in materials and achieve architectural simplicity and purpose. Most solutions to date have demanded abstruse calculations and complicated shuttering. The proposal is to provide a shape without complicated stresses (and their calculation) and yet to possess a shape that is simple to cast. The method is outlined in a well set out page of calculus, which looks deceptively simple. It probably is, but in any case the authors have produced sets of tables for varying shapes to be roofed. The result is a shell with principal stresses (compressive) in two directions, with neither shear nor tension. Consequently successful shells have been cast in reinforced lime concrete, made with brickbat aggregate, to a shape that "cast itself" with its shutters, set once to the correct profile, climbing without further complications to a successful finish.

Techniques for Flow Net Determinations

The theory of flow nets is set out in detail. It is difficult to follow and, in its more simple form, assumes properties of soil which do not exist. Stratification and variety of soil types in any full scale example make theory difficult to apply with exactness. The principle of a flow net, however, can be grasped, and a "flow net" drawn by freehand to give a reasonable solution to an otherwise impossible problem. In the article the theory is tested against some other techniques, to show the closeness of "fit" to certain examples where reasonable accuracy could be expected. The results show a good agreement between three different methods, thus indicating a measure of truth in all three. The fact that the "flow net" is a freehand estimate and not a detailed analysis has a value. It is easy to do and is unlikely to be trusted to be more than a "guide", thus ensuring a safety margin which is likely to cover the variations of soil type, changes in stratification, etc., actually encountered.

The paper is to be continued.

Moment Curvature Relationships for Axially Loaded Membus

This article analyses the problem of columns and struts using the Plastic Theory of design. It is very advanced, but should be noted by engineers in design offices as a useful reference.

Quality Controlled Concrete

The target is clearly defined to be to produce concrete of determined quality subject to a controlled variation. Without control, batches of concrete may vary in strength as much as 50 per cent up or down. This means that, to ensure that a minimum value is not exceeded, an average value 50 per cent over the design value must be set, with maximum samples 100 per cent stronger than the minimum. This often leads to very "rich" mixes, very dry and almost unworkable. By controlling the many variables of the mix this wide variation of strength can be brought to narrower limits. This may permit the selection of a cheaper mix, even one which is more workable, and still achieve the required minimum strength.

The paper describes what is needed, and sets out costs and values for average conditions. For example, the cost of a "trial mix" may run to £10–£14. A practical suggestion is that this mix can be placed in a base screed, or other low grade concrete position, so as to reduce the cost. The cost of test cubes is estimated at £1 each, which seems dear for a 6-in. cube of concrete. However, the saving in materials resulting from good control can be from 1s. 6d. to 2s. 6d. a yard cube. If the control ensures that no "bad concrete" has to be cut out and replaced, the control is well worth while.

Notes from *Civil Engineering and Public Works Review*, September, 1958

Engineering Developments in the U.S.S.R.

The extract describes a novel method of casting thin curved concrete shells. A layer of the mix is placed over elastic reinforcement on a metal sheet, which is vibrated. While the concrete is semi-plastic, the metal sheet is lifted up by two sides and forms a natural catenary. If a special curve is required, this is effected by means of templates. An ingenious method of bolting the metal sheet to a carrying frame enables the green casting to be moved into steam curing chambers.

The article then describes methods of using bamboo as a reinforcement for concrete. Permissible stresses are quoted, together with many practical details for obtaining reasonably uniform results from what would appear to be an unpredictable material. It is claimed that a reduction in cost of between twenty to forty per cent for beams up to 20 ft. span has been achieved behind the Bamboo Curtain.

A Direct Reading Nomogram for the Hiley Pile Driving Formula

The text and chart together give an easy answer to most of the problems for which the Hiley formula is suitable. This rules out frictional piles in soft clays or silts. The formula does not give the length of pile to be used, nor its size, but once these have been decided, the nomogram gives all the other answers that may be required.

Some Experimental Data Relating to the Design of Prestressed Concrete

This first part of the paper by Dr. S. C. C. Bate, considers the cracking and losses of prestress in concrete beams. The Author seeks to establish a simple design method which will (economically) account for such problems. He points out the susceptibility of high grade steel tendons to corrosion, and thus the danger of cracking during stressing, handling, etc.

Unless the state of pre-compression of the concrete is known (and this involves an accurate knowledge of the loss of prestress) it is not possible to ensure that, under load, the tension stresses finally achieved do not exceed the limit for preventing micro-cracking. Furthermore, it is possible that, in a period of years, a further loss of prestress might occur. The paper analyses the results of a number of experiments and compares practical measurements with both the theoretical results and also with the recommendations of the First Report in Prestressed Concrete.

THE UTILIZATION OF PULVERIZED FUEL ASH

The nature and properties of fly ash are clearly defined, and these lead to the discussion of possible uses in circumstances where the properties and economies of the situation encourage such use. The industrial uses considered are: as bulk fill; as an admixture to concrete; for soil stabilization; as a filler; as sintered light weight aggregate in concrete. There would seem to be an important use for fly ash in replacing peat in embankments, where the low density of the ash can be utilized.

THE SAFE USE OF LIFTING GEAR

This article is of interest to all engineers responsible for slinging heavy loads. It contains many useful warnings of errors which can cause serious accidents and damage. It would have been made much clearer had the author illustrated some of the points by the use of sketches.

T.W.T.

THE MILITARY ENGINEER

Journal of the Society of American Military Engineers.

"A Report on the French Economy" July–August, 1958.

A short review of the components of the French Economy with an estimate of future prospects, covering mineral resources and production, including the development of the Sahara oil fields, Industry, Power, Agriculture and the Conditions of Trade. The article also describes the formation, working and hoped for development of the European Economic Community. A useful bird's-eye view of the subject is obtained.

"Future Engineer Vehicles"

In order to overcome the difficulties imposed by the large variety of makes and types of mechanical equipment used by the army two multi-purpose "Military Specials" are under development. The article, after describing the disadvantages of the present state of affairs, gives a description of these new equipments, the B.A.T. (Ballastable All Purpose Tractor) and the A.B.C. (All Purpose Ballastable Crawler).

The former can be used for dozing and prime-mover operation, as a motorized scraper and for rough grading. The scraper bowl is carried between the two two-wheeled units the front one of which carries the dozer blade. The two operational components can be detached and replaced by a cargo carrying body converting the vehicle into a load carrier. The A.B.C. is a tracked vehicle with similar operational capabilities to the B.A.T. but with better mobility. The necessary weight is given to both equipments by ballasting with earth.

The B.A.T. design phase is complete and construction has begun of prototypes. The A.B.C. is still in the design stage. Tentative design and performance characteristics are given of both vehicles and there are illustrations.

"Man's Adjustment to Nuclear Force"

The U.S. Navy Bureau of Yards and Docks, in co-operation with the Automic Energy Commission, the Federal Civil Defence Administration, the Army Corps of Engineers and other Federal Agencies has been conducting research on the requirements of future construction to minimize the losses from possible nuclear attack. The article gives a brief account of their work and findings and describes the methods used to spread knowledge of the subject and overcome public apathy in relation to it. There are no strikingly new suggestions.

"Mr. Bailey's Civilian Bridge"

The above is the title of an article which gives an interesting and well illustrated account of the way in which standard Bailey bridging equipment, helped out in some cases by a few "specials", is being used for civilian purposes throughout the world. As well as quoting instances of the use of Bailey for emergency and permanent bridges, including a suspension bridge there are some interesting pictures and brief descriptions of construction work at two large dams, one in Canada and one in Scotland where Bailey equipment has been used extensively.

"The Antarctic Problem"

A short article on the military aspects and strategic importance and the complexities of international relations of and in Antarctica with a suggested solution that it should become a United Nations Protectorate. A useful summary of the subject.

MILITARY ENGINEER FIELD NOTES

(*a*) "Mechanical Mine-layer"

A good well illustrated description of a mechanical mine-layer which was successfully demonstrated at Stuttgart on 7th December, 1957. The mine-layer is towed by a M75 armoured personnel carrier which has been adapted to carry the mines. The layer has two plough-shares in echelon and the mines are fed down a shoot from the M75 into the furrow cut by the leading blade and covered by the earth turned up by the following one.

(*b*) "Air House"

A brief note on a type of structure which is available in the U.S. in several sizes and which can be used for providing covered space very rapidly. It consists of a nylon fabric neoprene coated shell which is blown up by an air blower and maintained by an internal air pressure of about three pounds per square inch. The building illustrated is 80 × 40 ft × 20 ft. high and was erected by a crew of twelve in five hours. The small bulk and ease of erection and transportation of an air house give it potential applications in war.

"Coast and Geodetic Survey"

A description of the organization and work of the Coast and Geodetic Survey with photographs of the principal officers.

"Fumigation Techniques in Structural Insect Control"

A description, with illustrations, of the method adopted in the Panama Canal zone for eliminating wood-destroying pests, particularly the dry-wood or powder-post termite which cannot be dealt with by isolating the structure as is possible with soil dwelling species. The method is to enclose the whole building in a plastic tarpaulin envelope and fumigate the whole volume with methyl-bromide. There are technical and engineering problems which are described and illustrated.

"Portable Military Shelters"

Description, with photographs, of a portable shelter, called Wannegan, constructed of glass reinforced resin made for the Canadian Army, with an account of the method of construction. The shelter can be packed for transport. The size of the shelter is 15 × 7 × 7 ft. and when packed it is 15 × 7 × 2½ ft. and weighs 2,000 lb. This includes 110 volt and 24 volt lighting systems, batteries and battery charger, and heating and ventilating systems.

"The Ledo Road Revisited"

An interesting account, illustrated with photographs, of the present condition of the Ledo Road connecting India with China through Northern Burma which was of so much importance in the war. The author was given every assistance by the Burmese authorities. The report is in some detail.

"Runway Repair"

Frost heave damage was caused by the freezing and thawing of waters trapped in pockets in the subgrade rock at Presque Isle Air Force Base, Maine. The article describes the scheme for improving the subgrade drainage and the difficulties of carrying it out without stopping flying.

Journal of the Society of American Military Engineers

SEPTEMBER–OCTOBER, 1958

"Disappearing Bridge"

It is often desirable to provide bridging across an obstacle in preparation for an operation without divulging to the enemy what is being planned. An American Engineer Battalion Commander has devised a method by which, using compressors, a standard class 60 rubber pontoon bridge can be sunk so as to be completely concealed and raised again to become a serviceable bridge. The device was successfully demonstrated to engineer officers from all over Germany and this illustrated note is a description of it. There is virtually no technical detail to show exactly how it was done or the special difficulties encountered.

"Class 100 Mobile Bridge. The Bridge of the Future"

This is still in the project stage and a description and photograph are given only of a model. Each floating pier is a conventional pontoon with its hollow section filled with styro-foam to make it unsinkable and a deck pivoting section on top. For transportation it is mounted on a tractor truck with a standard tandem dolly. The deck not only swivels round 90 degress to take up its travelling position but also folds inwards to the centre of the road way.

"Air-borne demolition teams".

The wide dispersion called for by modern tactical doctrine raise the problem of how to get the most out of the engineer units available. One essential is to reduce the time taken in moving between engineer tasks. This article describes how this can be achieved by the use of the H.4 helicopter with particular reference to the demolition tasks called for by an armoured cavalry regiment covering a corps in a withdrawal. The assumption made is that the cavalry and their supporting engineers are linked with W/T and that each engineer platoon has at least one helicopter standing by pre-loaded. A clear account is given of the action of the engineer platoon on the receipt of its first radio call.

Possible alternative loadings of the H4 are discussed according to whether the engineer party is to be returned by air, task completed, or whether a ¾-ton truck should be included in the lift to give the party its own mobility on arrival.

The basic idea of keeping the engineer troops relatively concentrated in reserve with adequate air transport immediately available has a much wider application than simply for demolition parties. It offers a means by which their usefulness can be very much increased, and their numerical weakness partly offset.

"Frozen Chosen Construction, and Engineer Rebuild Operations—Far East"

These two notes describe accommodation construction and plant rehabilitation carried out by Engineer Troops in Korea and Japan. They are interesting in relation to the first two articles reviewed in this number as showing the scale of the practical work being carried out by the American Engineers overseas.

J.S.W.S.

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada*, June, 1958

The June issue carries five papers which, while of little practical value to military engineers, provide some interesting information. The subjects include the corrosion behaviour of aluminium, the design and operation of an effluent disposal system for industrial wastes, and the economics of pumped storage with a mathematical analysis of power systems. An account of route selection through the Selkirk Mountains is spoilt by lack of a sketch map, and is rather fragmentary. A description of a punched card filing system may interest prospective consulting engineers.

Notes from *The Engineering Journal of Canada*, July, 1958

Canadian British Aluminium Project at Baie Comeau, Quebec

The opening, in June 1958, of the Canadian British Aluminium Company's smelter plant has established a new industry on the north shore of the River St. Lawrence. Three aspects of the project are described in separate papers in the July issue of *The Engineering Journal*.

Reduction Plant

Besides a well compressed description of the more interesting constructional and operational features of the plant, this paper contains a useful summary of project planning, site preparation, and major contract work. Good illustrations help the reader to appreciate the nature of the engineering work involved, and give added force to the list of planning points with which the authors conclude their review.

Smelter Dock

A new all-weather dock, providing sheltered berths for ocean-going vessels, was designed and completed in twenty-two months. The layout provides two fully sheltered berths for 10,000-tons ships and a third general cargo berth alongside the breakwater, while a fourth berth could be constructed at small additional cost. Sheet piling was used for the dock wall, the general pile length being 80 ft., reducing to 48 ft. at the end of the breakwater. Hydrographic and soil investigation, the design and construction of the loading dock, anchor walls, breakwater, and jetty ,and piling and dredging operations are described. This well arranged and interesting paper gives a concise, comprehensive account of a notable project.

Manicouagan Power Development

This paper is in two parts, the first describing a first stage of development in 1951–2, the second dealing with a further extension, in 1955–8, to provide part of the required supply at the Baie Comeau smelter plant.

Design of the initial project was based on hydraulic model studies, which led to the adoption of a most unusual method of draining the dam site without using cofferdams. This interesting example of diversion by tunnel resulted in lower cost, a reduction in hazard, and a considerable saving in time.

Project No. 2, providing power to the smelter plant through a two-circuit 161 kV. transmission line about eleven miles long, involved the installation of three 50,000 kVA. generators in an extension to the power-house, and the construction of a new gravity storage dam. Because of site restrictions several very interesting engineering problems arose. The bridging and blasting techniques adopted in their solution are of particular interest.

Modernization of Halifax Oil Refinery

This well illustrated paper gives a "birds-eye view" of an up-to-date oil refinery. Constructional engineering tasks are not discussed, but the over-all description of the project is impressive.

Notes from *The Engineering Journal of Canada*, August, 1958.

THE INTERNATIONAL GEOPHYSICAL YEAR

Canada is playing a large part in the programme of simultaneous measurements over the earth's surface during the International Geophysical Year, and many of her eighty stations are of particular value because of their location in the far north. The August issue of *The Engineering Journal* contains three papers dealing with the objectives of this international research organization, some knowledge of which is important to every modern engineer.

The first paper describes briefly the history and organization of the project, and the more important scientific objectives of each of the fifteen "disciplines" involved in the Canadian programme. The development of long range ballistic missiles, and of earth satellites, while increasing the practical value of much of the data being sought, serves also to facilitate its acquisition.

The second paper, "The CARDE I.G.Y. upper air research programme", reviews the objectives of the high altitude experiments of the Canadian Armament Research and Development Establishment, and includes interesting outlines of design considerations and assembly techniques affecting nose cones, and of instrumentation practice and the packaging of electronic components.

A short paper, "An observatory for the study of meteors", is of interest primarily for its historical summary, and because of collision risks affecting intercontinental missiles, space vehicles, and satellite space stations.

TUNNELLING SASKATOON'S STORM SEWER

Owing to its required depth, the soil conditions, and the need to avoid disturbing surface traffic and the existing water and drainage services, it was decided to install a 60-in. diameter storm sewer, 50 ft. below ground surface, by tunnelling. This paper describes the difficulties encountered in working through large pockets of water-bearing sand and silt, and various techniques which were tried to overcome them. There is no gilt-edged solution to the problem of unstable soil, and the best procedure in particular conditions had to be found by laborious and time-consuming experiment. Freezing and electro-osmosis were either unsuccessful or uneconomic, but the use of mechanical shields, short wood "piling", and concrete and chemical grouting were all found effective in differing conditions. R.P.A.D.L.

THE CONTRACT JOURNAL

Notes from *The Contract Journal*, July, 1958.

MORE GOOD PROGRESS WITH RUBBERIZED ROADS

The article refers to many uses of rubber in engineering which it may be of value to bear in mind. The resilience of a rubberized surface has solved several problems for engineers. Typical examples are heavily trafficked junctions, unusually steep gradients, and roads over peat. In Australia, rubberized bitumen is now being used for surfacing airfield runways, and has been shown to resist "fatting" in hot weather. In New South Wales, rubber pads have become customary for use with precast concrete railway sleepers, while in the U.K. the Cement and Concrete Association are experimenting with rubber to give a decorative finish to concrete.

NEW PLANT AND EQUIPMENT

A new idea in earth and concrete moving is the "multi skip" equipment. Similar to the now familiar mechanical horse which can operate several trailers, the Thwaites multi skip dumper and Bennes Marrell tipping lorry both combine one prime mover with a set of skips, in an effort to reduce "waiting time" loading and unloading.

Shaw Moisture Meters Ltd. have produced an electrode and indicator unit which can be installed in the weighing hopper and give the batching operator a visual dial reading of the water to be added with each batch of sand.

The Johnson Multibrator places an electric motor in the head of a poker vibrator. This permits a much lighter and longer electrical lead from a generator and eliminates the normal heavy flexible drive shaft from a static prime mover.

RESEARCH INTO BUILDING OPERATIONS

The annual report of the Building Research Station contains some very interesting details.

Packaged Bricks: very intelligent use has to be made of packaged bricks (and the full picture of savings from reduced breakages, etc., assessed) before the profit can be demonstrated. The cost of strapping involves a lot of salvaging.

Ready mixed concrete: savings are made when site reorganization enables the ready mixed concrete to be poured direct into its shuttering, or at the high rate at which the supply can be constantly maintained. Savings also can be proved where intermittent "idle time" mounts up for mixing plant static on the works site. Under more equal conditions such savings are not apparent.

Prefabricated houses. Problems, not apparent at a first glance, arise when the various systems are compared with "traditional" methods. Extra labour is involved in disguising the joints between panels, and in changing from fully prefabricated work back to traditional methods in the awkward places where prefabrication leaves off. This again points to the requirement for intelligent application of prefabrication, bearing in mind the shortcomings of the methods, together with good site organization to cope with the difficulties. (Note: a good example is reported in the same number of the journal where the erection of prefabricated offices at London Airport by Terrapin Ltd. is described.)

USE OF PRESTRESSED PRECAST CONCRETE IN GREAT BRITAIN

A report, presented by Mr. J. W. A. Agar and Mr. E. W. H. Gifford at the Third Congress of the "Federation Internationale de la Precontrainte" held in Berlin, gives details of common practice in British factories. Some of these are repeated below:

(*a*) Most units precast are pretensioned.

(*b*) Indented wire is popular: stranded tendons have not yet been used to any extent.

(*c*) Figures for the largest sizes of casting made by firms averaged around 60 ft. long and weighing 5–10 tons. The heaviest casting recorded was 86 ft. long and weighed 34 tons.

(*d*) Heat curing is seldom used, except in frost conditions, although accelerated curing has been found economical to achieve a rapid re-use of moulds.

(*e*) Chemical accelerators and workability aids are uncommon in use. Calcium chloride is particularly distrusted as a corrosive agent.

(*f*) High Alumina cement is not commonly used.

(*g*) Normal cube strengths required ranged between 6,000-8,000 lb/in.^{2} at 28 days. Transfer is normally effected at a cube strength of twice the applied prestress. A loss of 25 per cent prestress is normal (20 per cent in post-tensioned work).

(*h*) Progress is being made in casting hollow section beams. Moulds for I beams are complicated and it is easier to stretch wires through the middle of a beam and wrap Sisalkraft paper to form in inner core to cast a hollow sectioned beam. A light gauge sheet metal former is an alternative.

(*j*) A works-site pretensioning bed can be made so that the bed can be flooded for water curing.

(*k*) Some firms dry pack a mortar of Ciment Fondu (or Portland Cement) and sand. Others caulk the mortar with a low water cement ratio. An alternative for large members is a wide joint, carefully shuttered, with a well vibrated concrete mix poured into the 2½ to 6 in. gap. Tendons passing through the joint can be kept free from binding by means of Ductube.

(*l*) It is not necessary to roughen the surfaces of the precast members when forming the joint.

(*m*) The most common difficulty in post tensioned work lies in threading tendons through internal ducts. Exact alignment, oversize ducts, or external tendons (subsequently protected by *in situ* concrete) help to overcome the difficulty.

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(e) 2nd Lieutenants	2 0 0	1 10 0	1 5 0
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Field Marshal Lord Ligonier and his personal Secretary Mr. Richard Cox. From a contemporary painting by David Morier in the possession of the Cox's & King's Branch of Lloyds Bank Limited.