THE ROYAL ENGINEERS JOURNAL—SEPTEMBER 1962 VOL LXXVI No 3

THE ROYAL ENGINEERS JOURNAL

Vol LXXVI SEPTEMBER 1962 No 3

CONTENTS

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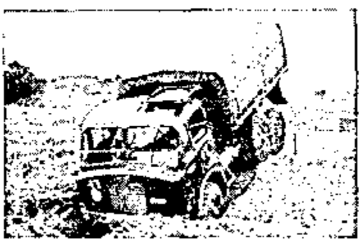

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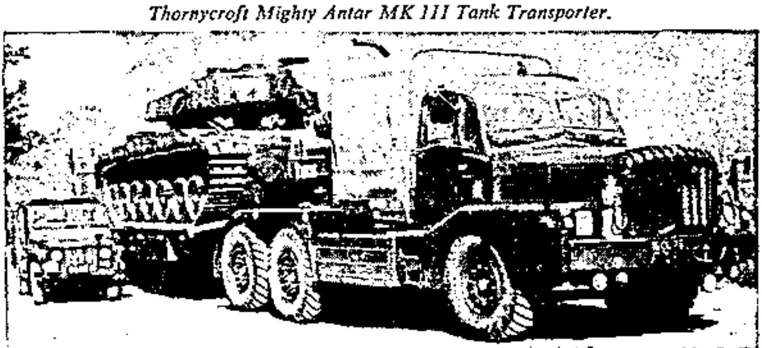

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VOL. LXXVI CONTENTS SEPTEMBER, 1962

Band of the Corps of Royal Engineers, Band of the Corps of Royal Engineers (Aldershot) and the Band of the Junior Leaders' Regiment, Royal Engineers on Brompton Barracks parade ground March 1962.

Band Of The Corps

The Royal School of Military Engineering

ALTHOUGH the Royal Warrant bringing the Royal Engineer Establishment at Chatham into being was signed on 23 April 1812 the festivities connected with its 150th Anniversary spanned the actual birthday date.

As a forerunner, on 14 March 1962, the Massed Bands of the Corps of Royal Engineers—the Chatham and Aldershot Bands and the Band of the Junior Leaders' Regiment—beat Retreat on Brompton Barrack Square the salute being taken by the Engineer-in-Chief, Major-General T. H. F. Foulkes, CB, OBE. A slim, elegant flagstaff had been erected on top of the Crimean Arch from which, for the first time, gently fluttered the Corps Flag against a black, snow-laden evening sky. The scarlet jackets of the Junior Leader bandsmen and the fitful snow flakes steadily falling upon the stoic, heavily muffled spectators produced a true Crimean atmosphere. "Follow the Sapper! Quick March!"

The principal festivities connected with the 150th Anniversary were, however, reserved for the more estival month of July as though, even after 150 years, the military engineering school at Chatham still wished coyly to disguise her true great age. To mark the occasion of the Anniversary the following message was sent by the Commandant, Brigadier E. F. Parker, OBE to Her Majesty The Queen, our Colonel-in-Chief:

"*In 1812 the Prince Regent, in the name of and on behalf of King George III, approved the Royal Engineer Establishment for the 'Instruction of our Corps of Royal Military Artificers, Sappers and Miners as well as the Junior Officers of our Corps of Royal Engineers in the duties of Sapping, Mining and other Military Fields Works'.*

The Commandant and all ranks of the Establishment—now the School of Military Engineering—on the occasion of its 150th Anniversary send to Her Majesty The Queen, their Colonel-in-Chief, their loyal greetings and heartfelt good wishes."

To which Her Majesty most graciously replied:

"*I send my sincere thanks to you and all ranks of the School of Military Engineering for the kind message of loyal greetings and good wishes which you have sent to me on their behalf on its 150th Anniversary. I warmly congratulate them on the completion of their first 150 years and send my good wishes for the future of the School.*"

ELIZABETH R, *Colonel-in-Chief.*

Amongst other messages received were the following:

"*All Ranks Royal Canadian School of Military Engineering send warmest congratulations on your achievement of reaching the dignified age of 150 years.*"

"The Representative Colonel Commandant, Engineer-in-Chief and all officers of the Corps of Australian Engineers send congratulations on the occasion of the 150th Anniversary of the School of Military Engineering and best wishes for the undoubted success of all the Anniversary celebrations."

"On the occasion of the 150th Anniversary of the School of Military Engineering and Foundation Stone Laying ceremony of the new building by HRH The Duke of Edinburgh, the Commandant and All Ranks of the College of Military Engineering, Kirkee (India) send their heartiest greetings and good wishes."

"The Mayor and Council of Gillingham wish to offer their congratulations to their Freemen on this historic event and we are proud and honoured at the long association of your Corps with the Borough."

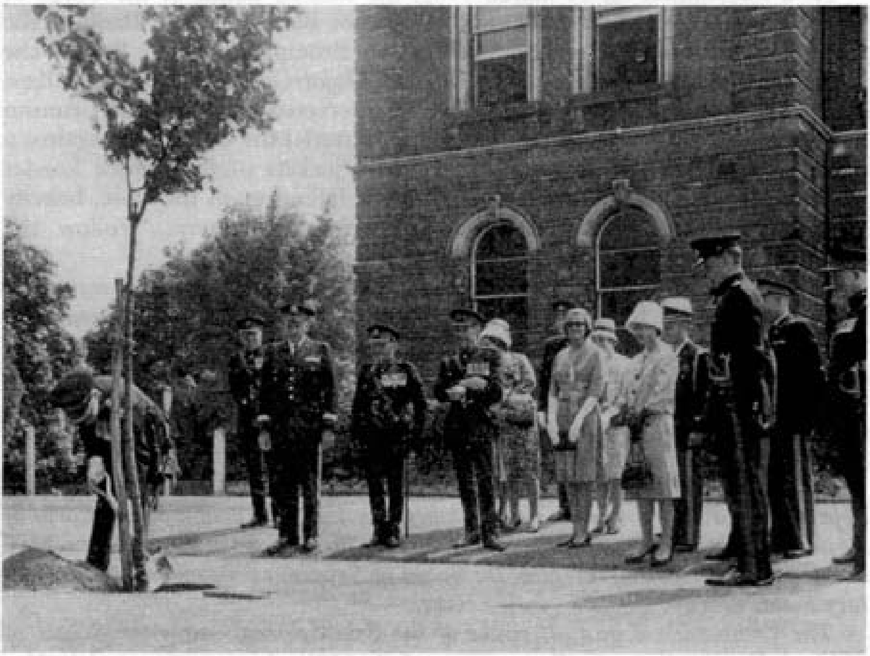


Photo by Chatham Observer

Colonel W. K. Lye, MBE, CD, Commandant Royal Canadian School of Military Engineering, planting the maple tree. Among those watching are Major General Lawrence P. Lincoln, Commanding General, United States Army Engineer Center, and Brigadier E. F. Parker, OBE, Commandant, School of Military Engineering, Chatham.

Study Centre of the new barracks to be built at Chattenden. Later in the morning, exercising their right as Freemen of Gillingham, a Royal Engineer contingent under the command of Lieut-Colonel A. F. Leslie, MBE, RE, Commanding Officer 12 SME Regiment, marched through the town with bayonets fixed and drums beating, the salute being taken by the Mayor of Gillingham, Alderman P. F Cooper. Following the parade, the Mayor and Mayoress of Gillingham entertained RE Officers, civic heads and other guests at a reception at the Municipal Buildings.

That evening the Royal Engineers' Ball was held in the Headquarter Mess, dancing continuing into the small hours of Thursday.

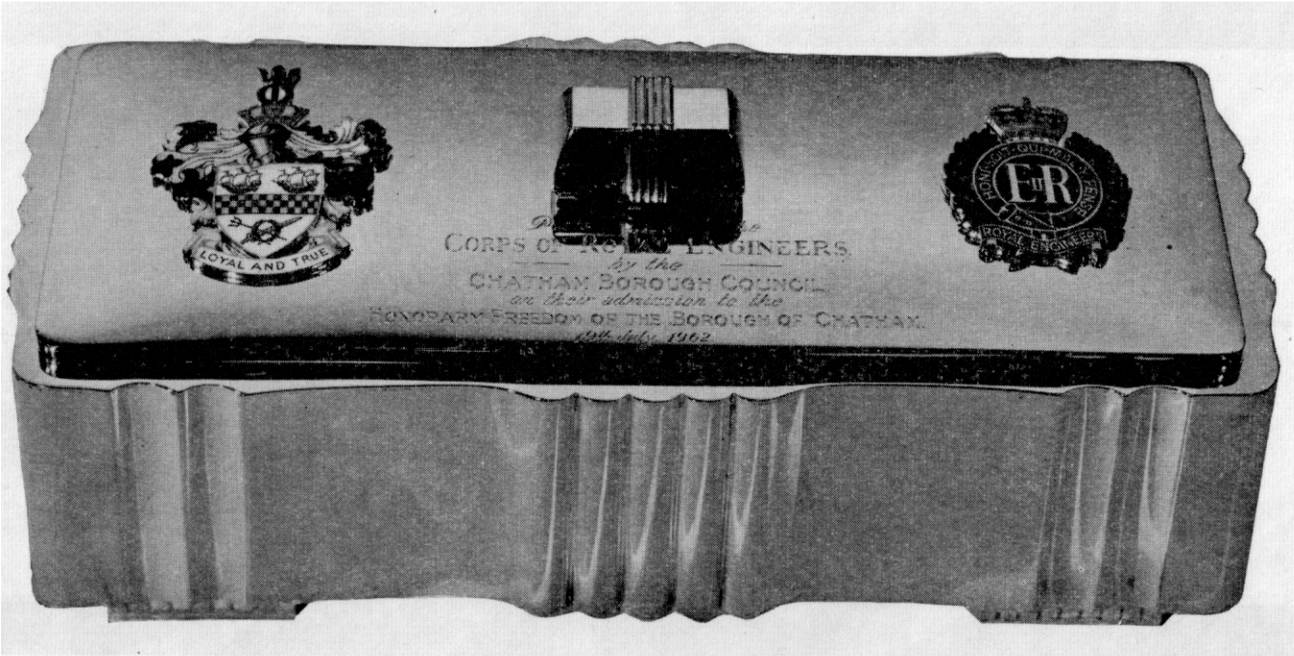
19 July saw the granting of the Freedom of Chatham to the Corps of Royal Engineers. Before the parade the Worshipful the Mayor of Chatham, Councillor Mrs Bertha Grieveson, JP, and the Corporation entertained the Chief Royal Engineer, General Sir Frank Simpson, GBE, KCB, DSO, and other guests at a Civic Luncheon in the Town Hall, Chatham. The Freedom-giving parade was held in Kitchener Barracks, Chatham, the parade being commanded by Lieut-Colonel J. Gordon, RE, Commanding Officer, The Depot Regiment RE, and the Casket Party and Escort being commanded by Lieutenant P. J. Worthington, RE. On conferring the Freedom of the Borough to the Corps of Royal Engineers the Mayor drew attention to the fact that the very first Freedom of Chatham had been bestowed in October 1902 upon a famous Sapper—Field Marshal Viscount Horatio Kitchener of Khartoum for his distinguished services in the South African War—and it was fitting that the present ceremonies should be held in the Barracks that bore his name. She went on to say that they were proud of the outstanding achievements of the Corps of Royal Engineers and took special pleasure in the fact that the School of Military Engineering, an integral and important part of the Corps, had been so long established at Chatham. In his reply General Sir Frank Simpson on behalf of all ranks of the Corps of Royal Engineers, both serving and retired, thanked the Mayor for the high honour conferred and said that he was very conscious of the long and historic association of the Corps with the town which dated back to the sixteenth century. He spoke warmly of the way the Borough had always taken so keen an interest in the affairs of the Corps and of the friendly and tolerant attitude of the civil population. It had given the Corps its highest recruiting rate—and the best marriage rate. Following a General Salute the parade marched past the saluting base and off the parade ground to march through Chatham with bayonets fixed, drums beating and band playing. The many spectators, which included the Rt Hon John Profumo, Secretary of State for War, were later entertained to tea in the Kitchener Barracks Officers' Mess and before her departure the Chief Royal Engineer presented to the Mayor of Chatham, on behalf of the Corps, a silver rose bowl as a memento of the great occasion.

Friday, 20 July 1962 marked the visit of His Royal Highness, The Duke of Edinburgh, KG to the School of Military Engineering, an auspicious date in the School's long history. The Duke arrived in a bright red Whirlwind helicopter of the Queen's Flight, touching down at the United Services' Sports Ground, Brompton. It was the first Royal visit since Her Majesty The Queen came to the SME in October 1956 on the occasion of the centenary of the incorporation of the Corps of Royal Sappers and Miners into the Corps of Royal Engineers. On alighting from the hellicopter the Duke was received by the Lord Lieutenant for the County of Kent, the Lord Cornwallis, the Chief

Photo by Chatham Observer

The Chief Royal Engineer, General Sir Frank Simpson, GBE, KCB, DSO, accepting the Freedom Casket and Scroll from the Worshipful the Mayor of Chatham ,Councillor Mrs Bertha Grieveson, JP.


BOROUGH OF CHATHAM
To the Chief Royal Engineer, The Officers, Warrant Officers, Non Commissioned Officers and Men of the
CORPS of ROYAL ENGINEERS
Greetings
We the Mayor, Aldermen and Burgesses of the
Borough of Chatham
in the County of Kent fully realising and appreciating the great record and glorious traditions created by the Corps of Royal Engineers in loyal and devoted service to our beloved Sovereigns and Country in all theatres of war since your most distinguished Corps was formed and with a view to recognising your long and historical association with this Borough
do by these Presents confer upon you
The Freedom of the Borough
and thereby the right, privilege and distinction of marching through the streets of the Borough on all ceremonial occasions with bayonets fixed, drums beating and bands playing



The Royal School Of Military Engineering 4.

Royal Engineer, the Engineer-in-Chief and the Mayor of Gillingham with his Town Clerk. The Duke then travelled by car to Brompton Barracks by way of Pasley Road. After passing under the Crimean Arch he was met by the Commandant, his own personal standard was broken at the flagstaff surmounting the Arch and the trumpeters of the Corps Band sounded a fanfare. After inspecting a Guard of Honour, commanded by Captain D. M. A. Quirke, RE, Adjutant 12 SME Regiment, His Royal Highness proceeded to the Headquarter Mess. Before luncheon certain officers and their ladies, including our American and Canadian guests were presented. In addition to the Royal Party one hundred and eighty officers and their ladies attended the luncheon in the Headquarter Mess amongst whom were the Representative Colonel Commandant, Major-General G. N. Tuck, CB, OBE, and eight previous Commandants of the School of Military Engineering; unhappily neither Lieut-General Sir William Dobbie, GCMG, KCB, DSO nor Major-General R. P. Pakenham Walsh, CB, MC, was able to be present. The Corps Band played during the luncheon, their first piece being a march entitled "150th Anniversary", composed specially for the occasion by Major W. G. Lemon, ARCM, RE, Director of Music.

After the Loyal Toast His Royal Highness announced that Her Majesty The Queen, as a birthday present, had graciously bestowed upon the School of Military Engineering the Royal title, from now onwards to be known as the ROYAL SCHOOL OF MILITARY ENGINEERING. The announcement was received with excited, tumultuous and thunderous acclamation. As all good birthday presents should be, this particular one had been kept a closely guarded secret. Nevertheless certain preliminary work had been done; almost as soon as the announcement had been made a glistening new name board had replaced the old one by the Gymnasium indicating the way to the Royal School of Military Engineering.

After luncheon His Royal Highness visited the grounds of the Construction School where he saw Sappers undergoing trades training and combat engineering instruction. He then flew to Chattenden in his hellicopter to lay the Commemorative Stone of the new Barracks that will house the Combat Engineering Group of the RSME. On his arrival he was met again by Lord Cornwallis who presented to him the Chairman of the Strood Council, Mr C. Higgs, and the Mayor of Rochester, Alderman J. Green, JP. He also met the Mayor of Chatham and senior members of the Works Organization and consultants concerned with the new barracks project, models of which were shown to the Duke. Brigadier P. O. G. Wakeham, OBE, a former Sapper, is the Senior Partner of the firm of Architects who designed the new Barracks and provided His Royal Highness with an ivory gavel with which to lay the Commemoration Stone. After the ceremonial laying His Royal Highness most graciously presented the gavel to the Headquarter Mess. When he had well and truly laid the stone the Duke said that: "The Duke of Wellington proved his greatness by establishing this School, but later his horror of change landed the Army in the administrative chaos of the Crimean War. You would think this was a sufficient lesson. But this last war began with people digging the same trenches their fathers dug twenty years earlier. It cannot be said too often that while one can learn from the principles of the past one must use the practices of the present. Learn from past failures and successes, but always look ahead and plan ahead. Any idiot can go on doing what has been done before, but it takes real courage, intelligence and character to assess the

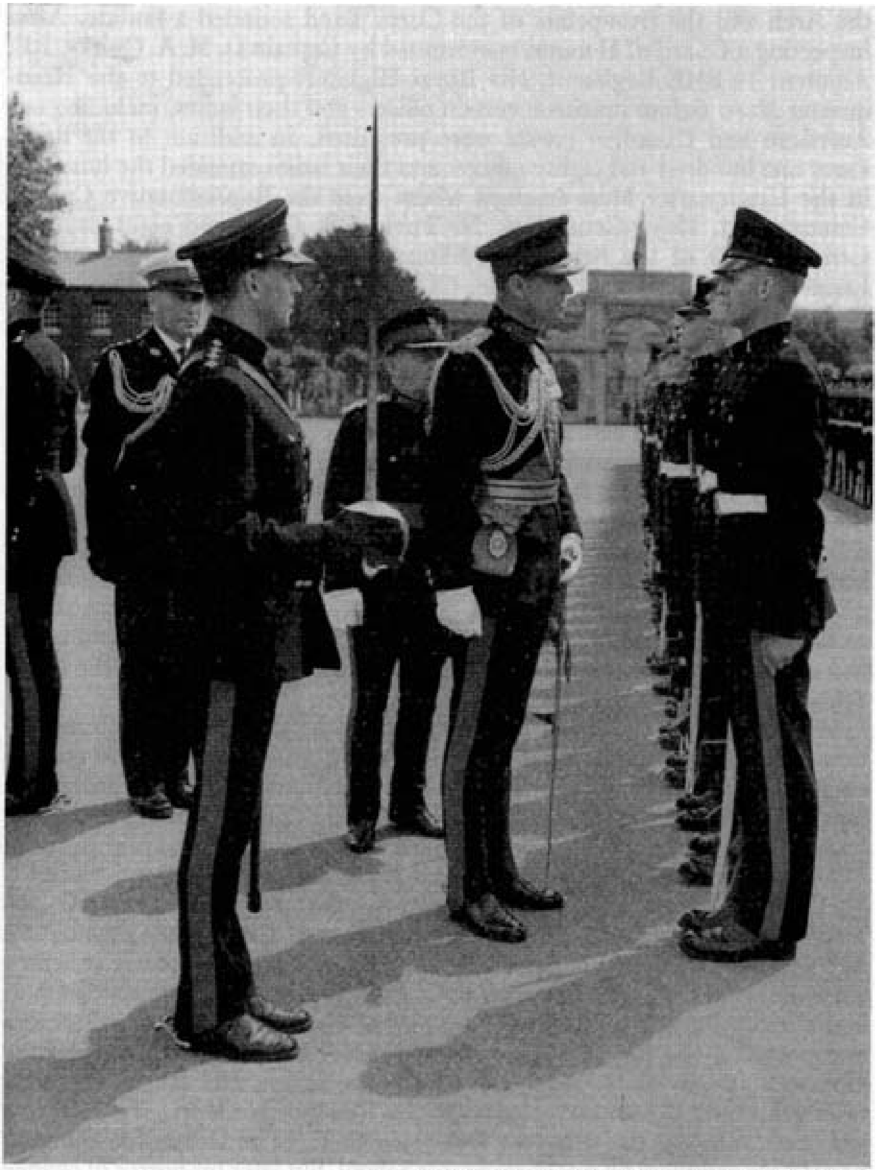


Photo by the Sport and General Press Agency Ltd, Fleet St, EC4

HRH the Duke of Edinburgh inspecting the Guard of Honour, talking to Staff Sergeant R. Willmott RE Drill and Weapon Training Instructor, Depot Regiment RE.

The Commandants, past and present.

L. to r.: Major-General G. W. Duke, CB, CBE, DSO (1956–9), Brigadier C. E. A. Browning, CBE, MC (1951–4), Brigadier H. T. S. King, OBE (1943–5), Major-General N. A. Coxwell-Rogers, CB, CBE, DSO (1941–2), Brigadier E. F. Parker, OBE (1959–), Brigadier M. Luby, DSO, MC (1940–1), Major-General D. Harrison, CB, DSO (1942–3), Brigadier B. T. Godfrey-Faussett, CB, CBE, MC (1945–8) and Major-General H. C. W. Eking, CB, CBE, DSO (1954–6).

Lieut-General Sir William Dobbie, GCMG, KCB, DSO (1933–5) and Major-General R. P. Pakenham-Walsh, CB, MC (1939) were unable to attend the 150th Anniversary Celebrations.

HRH the Duke of Edinburgh talking to a Sapper undergoing trades training. Major-General T. H. F. Foulkes, CB, OBE, Engineer-in-Chief, is standing behind the Duke.

HRH the Duke of Edinburgh laying the commemoration stone.

Photo by The Sport and General Press Agency Ltd, Fleet St, EC4

The commemorative stone laid by HRH the Duke of Edinburgh. The stone bears the Corps Badge (the Royal Arms) the Duke's personal Coat of Arms and the Royal Engineers cap badge of the reign of Queen Elizabeth II.

needs of the future, to devise a sound programme and carry it into effect. This is particularly true of the armed Services, which become merely an expensive luxury unless the process of improvement, modernization, forward thinking and planning goes on continuously."

The Commandant, Royal School of Military Engineering later sent the following message to the Duke of Edinburgh:

"The Commandant, Royal School of Military Engineering, respectfully thanks His Royal Highness for visiting his command on 20 July 1962 and for allowing the gavel used by him when laying the Commemorative Stone of the new Wing of the School to reside permanently in the Officers' Mess. He humbly wishes also, on behalf of all ranks of the Corps serving at Chatham to be associated with the Chief Royal Engineer's response to the great honour given to the School by Her Majesty in recognition of our 150th birthday."

Saturday, 21 July saw the Reunion of the Royal Engineer Veterans, and the first of the festivities at Chatham connected with the Golden Jubilee of the Royal Engineer Association were celebrated. In the evening the Band of the Royal Engineers and the Band of the Junior Leaders Regiment, Royal Engineers beat Retreat on Brompton Square watched by a large crowd.

After the National Anthem a most touching ceremony took place when M. Lucien Barret, President of the Federacion Ancien du Génie, presented medals of fidelity and honour; gold medals were presented to the Royal School of Military Engineering and to the Commandant, silver medals to Lieut-Colonel J. Gordon, RE and to Mr R. Dummer, General Secretary of the Royal Engineer Association, and bronze medals were presented to Mr J. Walker (former General Secretary REA) in his absence and to WOI RSM G. Handley, RE of 12 RSME Regiment. A plaque was also presented to the RSME on behalf of the French Engineer School at Anger. M. Lucien Barret commanded a battalion of Maquis during the war and later a battalion of French Engineers in North Africa. With him came, as Corps guests to Chatham, seventeen members of the Federacion Nacional du Génie, eight officers and nine warrant officers of the Reserve of French Engineers with their Standard. They headed the march past followed by the Standards of the Newport, Eastbourne, Tunbridge Wells, Hastings, Maidstone and Chatham Branches of the Royal Engineers Association. Brigadier E. F. Parker took the salute supported by M. Lucian Barret and Colonel T. Burrowes, OBE, Sub-Group Director of the South Eastern Sub-Group of the REA.

The Royal Enginers Memorial Service in Rochester Cathedral on Sunday, 22 July drew the festivities to a close. The Cathedral, so steeped in Sapper connexions and containing so many Royal Engineer memorials, was filled with past and present members of the Corps. The address, a most stirring one, was given by The Right Reverend The Lord Bishop of Rochester, Dr R. D. Say. After the service the Corps of Royal Engineers exercised their right as Freeman to march through the City of Rochester, the salute being taken by The Right Worshipful The Mayor, Alderman J. Green, JP, and the Chief Royal Engineer. The contingent, commanded by Lieut-Colonel A. F. Leslie, MBE, RE, was able to march back to Brompton Barracks through Chatham and Gillingham thereby exercising their right as Freemen of the three Medway Towns.

The Mayor of Rochester most kindly entertained officers and their ladies

M. Lucien Barret presenting fidelity and honour medal to Mr E. Dummer, General Secretary, Royal Engineers Association.

The procession from the Cathedral to the Guildhall after the RE Memorial Service.

at the Guildhall after the parade, before the luncheon given in the Headquarter Mess. At this latter function Major-General Lawrence P. Lincoln presented, on behalf of the United States Army Engineer Center, Fort Belvoir, a shield to the Royal School of Military Engineering.

And so ended five historic days.

A vast number of messages have been received, headed by one from the Sappers in Germany, and from the Chief Engineer, New Zealand Forces who was visiting the Engineer Base Group, Singapore, congratulating the Royal School of Military Engineering on its new title, and Brigadier E. F. Parker, OBE, on being the first Commandant of the Royal School.

Engineer-in-Chief's Address to the 1962 Annual General Meeting of the Corps

MAJOR-GENERAL FOULKES opened his address by saying that this was the last occasion on which he would have the privilege of addressing the meeting as Engineer-in-Chief. He did so after more than two years in the appointment, during which time he had been able to visit and see for himself every aspect of the work of the Corps.

As he had indicated two years ago, the Corps had been, and still was, in a period of galloping evolution, brought about largely by the reduction in size of the Army and the arrival of new weapons. As a result of the 1962 Defence White Paper, we, in common with the rest of the Army, must now expect further changes, but they were likely to be less drastic than those already experienced.

One theme of this White Paper was a measure of integration of the Services; and it might well be advisable for officers to prepare their minds for some convergence of various sections of the Corps which had hitherto existed in separate compartments. In Cyprus a single engineer organization would be established soon, under one CRE, who would be responsible for Field, Resources and Transportation duties, as well as the Corps aspects of Postal and Movements. In the War Office, unified professional control of most of the Corps had been re-established for the first time since the regrettable division in 1904. The unity of the Corps was essential to its health and effectiveness.

The E-in-C then spoke of Corps activities during the past year, which had been remarkable for their number and variety. Lack of time prevented him from mentioning much fine work that had been done.

ORGANIZATION

On the subject of organization he noted that there had been no major changes during the year, though the long-term decision to man the Movement Control Service with RE officers was an important one for the Corps and would, incidentally, provide additional outlets on the Staff and elsewhere. The scope of Movements training on the Long Transportation Course was being increased accordingly.

68th Gurkha Field Suadron had arrived on Salisbury Plain in May and now formed part of the Strategic Reserve. The E-in-C said that these fine soldiers and good tradesmen were very welcome.

The Reserve Army was settling down after its big reorganization of last year and recruiting for some units was very good. Certain of the Transportation units in Category I of the Army Emergency Reserve were nearly up to 100 per cent volunteer strength. Others were facing difficulties.

The RE Combat Development Staff had continued their valuable studies of the future. They had, on his authority, produced a guide to future engineer organization; and they had other irons in the fire.

Methods of closer co-operation with the Royal Marines were being worked out, and some advance had been made.

The E-in-C mentioned the very successful Tripartite Engineer Conference which he had attended at the Royal Canadian SME at Chilliwack, near Vancouver, last November. Good progress had been made since the previous Conference, and the close affinity between the Engineers of the USA, Canada and Britain had been very evident.

Training

The last two training regiments had been amalgamated, so that now the Corps had only 1 Training Regiment, at Cove. This would eventually be located in a new barracks beside Hawley Lake—a sad break with the tradition of Aldershot but necessary to efficiency.

The rebuilding of the SME would start soon and was due to be completed in 1966. Gordon Barracks at Gillingham would be given up, and a new barracks would be built North of the River Medway at Chattenden. The RE Park would also be rebuilt.

Reserve Army training this year had been exceptionally interesting and enterprising. A good deal about it had appeared in the papers.

Equipment

The most important event in the field of RE equipment had been the acceptance for service of Amphibious River Crossing Equipment. The Army were now going to purchase the German M2 version, and not the French Gillois, and a specialist unit was being formed to operate it.

29th Field Squadron in Germany now had two small helicopters on its strength for trials of integration of aircraft into Army units.

The Centurion AVRE and bridgelayer should both be with units by the end of this year. The E-in-C welcomed this in view of the great importance of armoured engineers.

A War Office decision that power generation in forward units was to be at 400 cycles per second would have far-reaching results. Electrical equipment of this kind was much lighter than air-compressors and pneumatic tools. But it would take time to provide.

Personnel Matters

Except in the most senior ranks, redundancy of officers was all over—as was other rank redundancy.

All the eight Young Officers who had taken the Tripos at Cambridge this Summer had got honours degrees. This was better.

During the past year, the Corps had been joined by twenty-three Young Officers from Sandhurst, including three SUO's and seven JUO's; and practically all were fit to take an honours degree. This year, the Corps expected to get thirty-nine from Sandhurst as compared with twenty-three last year, and the batch of twenty-two due to be commissioned in August contained another three SUO's and another seven JUO's. The winter batch had not yet been allotted their ranks. Seven officers were expected this year direct from universities, as against an average of about one a year in previous years.

Good as all this might look, it was not nearly good enough. The Corps was very short of Junior Officers and the deficit was increasing annually. Officer recruiting had now become our greatest problem. The E-in-C was sure that this problem could be solved; but the first essential was to make widely known in schools and homes—often through deaf ears—the startling advantages of a commission in the Corps: pay, free education, variety, responsibility and all the other things serving officers knew about; apart from which, the current shortage made prospects of promotion in the Corps quite outstanding in years to come. In other rank recruiting, Special RE Recruiters had done a great deal to improve the situation, but in officer recruiting they were not allowed; and it followed that every Sapper officer, serving or retired, was needed as an unofficial special recruiter. Our combined influence in this respect was vast, if used; and the E-in-C said, that anyone who had not been in contact with his old school of late, just to remind them that the Corps existed, had done less than he might for officer recruiting. The public in general was oblivious of the existence of the Corps. If officers wanted recruiting material, E1 would provide it.

The E-in-C commended to officers' attention our two recruiting publications. *Follow the Sapper* was concerned with attracting potential officers, while the *Other Rank Recruiting Book* gave a very good guide to all the activities and attractions of the Corps.

It was pleasing to report a dramatic improvement in other ranks recruiting, but past experience had shown that we could never relax. The Corps had reason to be grateful to all those who had contributed to this remarkable achievement. The priority he had necessarily given to the recruiting and recruit training organizations had caused a severe strain on many units, particularly during a manpower shortage. Apart from which, it had been necessary at one and the same time, to reinforce Germany, strengthen units in the Middle East and participate in a succession of widespread emergencies. The combined recruiting effort, had, however, done much to lay the foundations of the Corps of the future.

Engineer Services

In the important field of Engineer Services, the last twelve months had been a testing time for the ESSE establishment. So soon after its birth, it had had to deal with cold war emergencies and natural disasters, such as the Cameroons, Kuwait, Bahrein, Christmas Island and British Honduras. It had done very well but it had been overtaxed; and its organization was being reviewed. It was hardly surprising that Sappers were continuing to prove themselves indispensable for emergency accommodation tasks overseas, since one of the three basic functions of the Corps was to help the Army to *live*, as well as to *move* and to *fight*. The history of the Army was the story of the hardship and endurance, as well as the renown, of the British soldier; and the greater the administrative risks that were taken, the more insistent was the subsequent cry for Sappers to alleviate the misery of the soldiery. Moreover, there were at least signs of realization that it might be unwise to dispense altogether with the services of the Corps in accommodating the Army at home.

There was no time even to list the more exciting engineering projects on which officers and other ranks of ESSE were employed, but they included the Canadian North-West Highway System, the Australian Snowy Mountains project and three different nuclear power stations at home.

Corps Matters

This year, in addition to the 150th Anniversary of the SME, we were celebrating the Jubilee of the RE Association. This would culminate in a Rally at the Royal Festival Hall and ceremonies at the Cenotaph and on the Horse Guards Parade.

The Corps had also taken a modest part in the celebration of the 50th Anniversary of the Royal Flying Corps. The Army were very creditably represented at the Cenotaph by a guard found from 9th Independent Parachute Squadron. Though 1962 had been publicly described as the Jubilee of "British Military Aviation", the E-in-C had had the pleasure of mentioning to two Ministers of the Crown that the Air Battalion, RE, was *disbanded* on the day the Royal Flying Corps was *formed*.

Among its many successful engagements the Corps Band had given a good account of themselves at the Shakespeare Birthday Celebrations at Stratford and had been heard by many thousands.

We had continued to hold our own in many fields. Of the fifteen brevets given in 1961, four had gone to Sappers. Four Sappers were on the current course at Latimer. Three Sappers had been selected for the IDC next January. A Sapper was soon to become a College Commander at Sandhurst.

The E-in-C was sorry to announce that MEXE was losing Sir Donald Bailey in the Autumn, but he would remain in personal contact with many members of the Corps in his new appointment as Dean of the Royal Military College of Science. We wished him well, this old friend. MEXE itself continued to give us very close and efficient support.

Major-General Foulkes said that he had long been conscious of the need to ensure that the Army as a whole understood and valued the potentialities of its Sappers, and this feeling had been reinforced by the absolute certainty that there had never been a period when the Army had had greater need of them. There had been, and was, no lack of good will towards the Corps, especially among officers of mature practical experience; but at a time of rapid evolution such as the present, and one of great military scarcity, there must inevitably be adverse forces at work. Who but officers of the Corps itself could make its potentialities better known?

He believed, however, that there were far too many Sappers, who, from working in watertight compartments within the Corps, or making a career outside it, or for other reasons, had come to lack a proper understanding of its character and essence: a dangerous situation and one that had to be rectified if at all possible. Hence his addiction to talking about the Corps in public and his frequent appearances in print.

He hoped that some of the things he had been saying in the last two or three years would be remembered, and perhaps made use of, by all and sundry; and that those officers who might one day hold heavy responsibility for Corps affairs, and others who might rise to high places in the Army, would take particular note of them. They had been printed in the *Journals* of September 1960, March 1961 and September 1961. There were also his periodical Liaison Letters, and the lectures he had given each January at Shrivenham.

The E-in-C concluded his speech by saying

"It all boils down to this:—

"First: we must understand the meaning of the profession of Military Engineer, and its value to all efficient armies, and must maintain a proper balance between our military and technical capabilities.

"It follows, secondly, that we remain in the unique and enviable position of being the only corps of officers who are wholly combatant and, at the same time, fully technical. Our young officers must, therefore, be selected from boys who possess a combination of brains and leadership.

"Thirdly; our standards of performance, individual and collective, must never be anything less than excellent, or no precepts will be of much avail.

"Finally: our attitude must always be one of the greatest possible helpfulness to the Army as a whole, which we must be ready and eager to support at all times and places, however inconvenient or unpleasant, come hell or high water—as we have always done in the past.

"In conversation, by lecturing and in writing, please pass it on. We owe this to the Army no less than to the Corps itself."

150 Years of the Royal School of Military Engineering and the Early Days of Military Flying

BRIGADIER (GROUP CAPTAIN) P. W. L. BROKE-SMITH, CIE, DSO, OBE, who was Adjutant and Instructor of the Air Battalion RE until the responsibility for military flying passed from the Royal Engineers to the Royal Flying Corps in 1912 has made some interesting comments on the early aeronautical photographs that illustrated Lieut-Colonel E. E. N. Sandeman's article on 150 years of the SME, published in the March 1962 issue of the *RE Journal*.

In referring to the photograph on page 14 of the March *Journal* he says that the balloon shown in the illustration is being "topped up" in accordance with the normal practice from a single tube wagon that always accompanied a filled captive balloon in the field. To fill a balloon with gas a group of three tube wagons was necessary. The tube wagons in use in 1896 each carried thirty-eight 1883 pattern 8 ft × 5⅛ in cylinders or tubes, about 100 of which were needed to fill a 10,000 cu ft balloon. In about 1898 higher pressure and larger, 10 ft × 8 in, tubes were introduced, nine of which were carried on one wagon. About twenty-two of these larger tubes were needed to inflate fully a 10,000 cu ft balloon. The 1898 type tube wagons were used in the South African War, often pulled by teams of oxen. During the South African War six Balloon Sections were raised and that number of Sections was maintained, with three at cadre strength, until all were absorbed into the Balloon School of 1906 which in turn was reconstituted as the Air Battalion in 1911 to provide the foundation of the Royal Flying Corps, inaugurated officially in 13 May 1912.

He also said that he was engaged in the trials on Laffan's Plain and subsequent operation of the man-carrying kites brought to Aldershot by Cody in June 1904. The Cody system, suitably modified for military purposes, was adopted in 1905 and kites then became an item of Sapper G1098 equipment.

The oblique air photograph taken from a kite in 1904 of the Medway, the Chatham Dockyard, St Mary's Barracks, the Ravelin and Kyber Pass Road, published on page 12 of the March *Journal*, is a remarkable example of early air photography. You can see clearly on the original photograph such detail as several dockyard maties walking quietly along the Kyber Pass Road reading their newspapers. This preoccupation in world affairs, the racing news or the pools in today's mad, mechanized rush to and from work would invite certain sudden death on the road. Brigadier Broke-Smith has, however, supplied an air photograph which is considerably older than the one published in the March *Journal*. When Captain Henry Elsdale, RE (later Colonel H. Elsdale) was serving in Nova Scotia in 1883 he carried out experiments in aerial photography in which he sent up small balloons carrying automatic cameras. The photograph supplied by Brigadier Broke-Smith is one of the Citadel Barracks, Halifax, Nova Scotia, so taken in 1883 from a balloon sent up by Captain Elsdale. It must be one of the oldest air photographs on record and Elsdale's balloons may be regarded as distant Sapper forbears of Lunik II.

Photograph of the Citadel Barracks, Halifax, Nova Scotia, taken in 1883 by an automatic camera carried in a small balloon.

Elsdale produced in 1883 an ingenious device for use with his small captive balloons which had a capacity of about 1,000 cu ft. On top of what was a very primitive type of camera were placed six photographic plates, resting one over the other with their prepared surfaces downwards. When the camera-carrying balloon was hovering over the area to be photographed, a clockwork mechanism was tripped by an operator on the ground. The camera shutter opened to give a very short exposure and then the plate was automatically slid to one side leaving the next ready for use. Plans made from these air photographs were found to tally closely with the actual dimensions of the places photographed. The following year Elsdale was given command of the RE Balloon detachment with the Bechuanaland Field Force, but other enthusiastic Sapper officers continued to experiment in air photography although no official backing, nor public funds, were forthcoming to assist them in their work.

Brigadier Broke-Smith was in his early days a qualified RE pilot of balloons, man-lifting kites, airships and powered aeroplanes. At the present Jubilee Celebrations of the Royal Flying Corps/Royal Air Force he was introduced to the Secretary of State for Air by the Engineer-in-Chief as the senior aeronaut present. In 1952 he wrote a factual account of the "History of Early British Military Aeronautics" which was published serially in the *RE Journal* of that year. The history starts in 1878 when authority was first given for the experimental production of military balloons and associated field equipments and Captain H. P. Lee, RE, and Captain J. L. B. Templer, of the Middlesex Militia, were appointed to carry out the experiments and granted the princely sum of £150 for the construction of a balloon. The history then covers the development and operations in peace and war of RE manned balloons, kites, airships and aeroplanes until the formation of the Royal Flying Corps on 13 May 1912. These articles, bound in book form, are available on application to the Secretary, the Institution of Royal Engineers, Chatham, Kent, price half a crown each.

Military* Use of Ground Effect Vehicles

The Engineer-in-Chief is keen to exploit the many and varied important applications which ground effect machines and variable ground pressure vehicles may offer to engineers to facilitate the water and country crossing ability of the Army.

It is considered that the republication of a record of a lecture on "The Military use of Ground Effect Vehicles" given to the Royal Aeronautical Society, and published in the May 1962 edition of their Journal, would furnish much information on the subject to Royal Engineer officers and would stimulate thought. Accordingly, permission was sought of the lecturer, Mr W. H. Coulthard, Deputy Director (Research), Fighting Vehicle Research and Development Establishment and of the Royal Aeronautical Society, and their assent is gratefully acknowledged. The article is published in full below.

At present, four lines of research on possible applications of ground effect machines or variable ground pressure vehicles for Royal Engineer uses being undertaken are:—

(a) Transportation uses of GEM machines.

(b) The application of the "Bubble" concept now being developed at RAE Cardington to make light ferry, about Class 6, for use on air transported operations, when the possibilities of saving bulk and weight would be invaluable.

(c) The variable ground pressure vehicle on a Land Rover chassis, an example of which was seen at the RE Demonstration this year, possibly mounting a mine-detector, coupled with a system of marking mines. Or it might be used as a vehicle which could cross a minefield and then pull over an explosive mine clearing hose or other device.

(d) A self-propelled amphibious Bridging/Ferry equipment the units of which would be small enough for normal road and cross-country movement, and which could be coupled together when in use. It would use the ground

* Military: of, done by, befitting soldiers (*Concise Oxford Dictionary*).

effect principle to improve cross-country performance and increase buoyancy, with corresponding reduction in size and weight of the unit. This has been proposed as a suitable subject for this year's design exercise at the RMCS Shrivenham.

It is proposed to hold a symposium in the autumn to discuss these and other promising uses which readers are encouraged to put forward. Any such ideas should be forwarded to Colonel R. L. France, AD/Development, DREE, War Office, St Christopher House, Southwark Street, London, SE1.

SUMMARY:—The lecture illustrates, by typical examples, the standard of mobility which can be achieved by present military vehicles. An outline is then given of the mobility improvements which might be obtained by the use of military ground-effect vehicles but, in the concluding section, emphasis is given to a number of generalised problems in the military operation of such vehicles which require detailed consideration before an adequate specification of ground-effect vehicles for military use is possible. The lecture deals only with overland vehicles—although capable of water crossing—which are designed specifically to exploit the ground-effect principle and whose capabilities for sustained airborne movement are limited to the ground cushion.

INTRODUCTION

Although this lecture will be concerned principally with a small part of the whole pattern of military aviation, a brief reference to this broader background will provide a useful introduction to the main theme.

While all armies are increasingly conscious of the advantages to be gained from the movement of military forces and stores by air instead of by land there are still many factors which limit the extent to which such airborne movement can be substituted for groundborne movement, particularly in forward battle areas. Airborne movement in these areas requires either forward airstrips, or the complexity of VTOL aircraft; also, forward area supply can be based on aircraft only within the known or predictable limits of their vulnerability and their capacity for reliable all-weather, day and night supply operation. This supply movement problem is one of considerable magnitude, for example, a typical fighting group, dispersed within a forward operational area which may be 12 miles in width and 10 miles in depth, could require a daily supply of up to 100 tons of stores. These present limitations of airborne movement are indicated not to minimise the importance of military aviation, but to emphasise that, in the foreseeable future, armies will continue to require groundborne support. Against this continuing requirement, therefore, it is proposed to examine the contribution which can be made by the applications of ground-effect principles to future military vehicles; the examination will be confined to landborne vehicles—although with a water obstacle crossing capability—which are designed specifically to exploit the ground-effect, but whose capabilities for sustained airborne movement are limited to the ground cushion. Free flight machines, such as helicopters and VTOL aircraft, even though they may benefit incidentally from ground-effects, are not considered in this lecture, although it is not intended, in omitting them, to under-assess the important contributions to military aviation of which they are capable, and some brief further reference to these is made in the concluding paragraphs. Since at present no military ground-effect vehicles exist, the lecture will endeavour to identify the military problems which may be alleviated, and the additional problems which may be created, by the use of such vehicles. It should be observed that, in a broad new field of this nature, it is at present quite impractical for firm military requirements to be stated and the lecture expresses only the author's views on the characteristics which appear most likely to lead to improved military vehicles in the future.

Present Military Mobility

The problem areas may be identified by considering the Army's present capabilities for ground movement. First, all military vehicles can, and must be able to, travel and manoeuvre on public roads, and existing vehicles are generally capable of road speeds, depending on the type of vehicle, in excess of 25 m.p.h. One of the main military requirements which distinguishes forward area military vehicles from their civilian counterparts is that for high performance and sustained movement across country; in addition to rough and soft ground crossing, military vehicles must climb steep slopes of the order of 1 in 2, traverse land obstacles, such as ditches, and wade or swim through water obstacles. These conditions, particularly also the Army's present capabilities, are not easy to visualise and, in view of their importance in evaluating under difficult conditions the possible contributions of ground-effect machines, the performance of two military vehicles, the Ferret, a wheeled reconnaissance vehicle and a tracked load carrier which is also capable of swimming, are noteworthy*.

Two further aspects of vehicle mobility should be mentioned. First, the average cross-country speed of present forward area vehicles is quite low, around 12 m.p.h.; over rough ground it is frequently the crew endurance, rather than the vehicle design, which limits the speed, so that any smoothing of the ride could have the direct effect of increasing cross-country performance. Second, the types of military vehicle illustrated can be disabled by small ground-laid mines, although if, like the Ferret, they are lightly-armoured, crew injury from such mines is unlikely; vehicle-operated mines are usually triggered at pressures of around 8/10 p.s.i. (*i.e.* over 1,000 pounds per square foot).

Possible Improvements and Problems Areas

Against the above background of military mobility it is now proposed to investigate the possible improvements which ground-effect vehicles might achieve on such performance in forward areas. These are considered the most profitable areas to investigate, as rear areas will tend to have more roads and less severe conditions, so that conventional vehicles can operate with reasonable efficiency.

Certain of the improvements which might be achieved are of considerable military value: they are, bearing in mind the type of going which was shown on the film:—

(*i*) increased speed across rough ground;
(*ii*) greater continuity of forward motion, irrespective of whether the surface traversed is hard ground, soft or water; and
(*iii*) increased obstacle crossing capability.

* The Lecturer demonstrated their capabilities with a short film.

These aims are summarised, particularly for logistic vehicles, in an improvement in their "ton-miles per hour" capability. A further aim of importance is to improve the ton-miles per gallon of fuel in such vehicles. This aim is not, however, likely to be compatible with the increased performance requirements and the importance of the ton-miles/gallon criterion will probably be restricted to its use for comparative purposes between alternative solutions; there is little prospect that existing standards of fuel consumption will be improved by ground-effect techniques.

Before investigating these possibilities, some aspects of forward operation can be eliminated as areas unlikely to be improved, although not as unimportant problems, at the present state of knowledge. The first of these is the application of ground-effect techniques to heavily armoured vehicles of the order of 40–50 tons in weight. The reasoning for this is illustrated in Fig. 1(*a*) which shows a typical modern 45 ton tank, including its area in plan view. If all this area were assumed available for support, the figure indicates that it would require a cushion pressure of 400 lb./sq. ft. to support the vehicle; this discouraging value is appreciably higher than that for the vehicles to be discussed later, as illustrated by Fig. 1(*b*), showing an unarmoured vehicle of about 12 tons weight requiring a cushion pressure just over 200 lb./sq. ft. Returning to Fig. 1(*a*) this value is due wholly to the high vehicle density associated with heavy armour. The surrounding line shows the area which would have to be enclosed before the pressure was reduced to 100 lb./sq. ft., which, by present standards, is high, although achievable, in a ground-effect machine. The many disadvantages in attempting to operate a vehicle with such a large and necessarily lightly-constructed surround are sufficient to suggest that, at present, the 40/50 ton tank is not a suitable subject for the application of ground-effect techniques. There is a further disadvantage with these larger vehicles, namely that their width, without additional surrounds, is already large for road usage. The Ministry of Transport maximum width for unrestricted road use is 8 feet, and, although military vehicles are permitted to exceed this figure (the tank illustrated is 11 feet wide), such widths can, on occasion, restrict their freedom of movement. These figures suggest that any surrounding structure must necessarily be detachable for road use, and, for the order of superstructure illustrated, such a major task conflicts with the requirement for free movement between road and cross-country.

The second potentially unprofitable design area is likely to be any attempt at present to improve the mine-resistant qualities of these vehicles. It is probable that the pressure fuses mentioned earlier, and even those of anti-personnel mines, will not be operated by ground-effect vehicles, although experiments will be necessary to establish this. Such experiments will also need to be extended to types of fuse which might be more specifically designed for operation by ground-effect vehicles, and these stages must be investigated before any vehicle work to improve mine protection can proceed. It should, however, be noted that, assuming a suitable fusing technique to be possible, ground-effect machines may be vulnerable to mines, both because of their probable reduced armour (for weight saving) and because the mines are likely to explode in the confined space beneath the vehicle, as distinct from normal vehicle mines which are exploded by the wheels or tracks to one side of, and some distance from, the vehicle hull.

Turning now to more profitable regions of investigations, two representa-

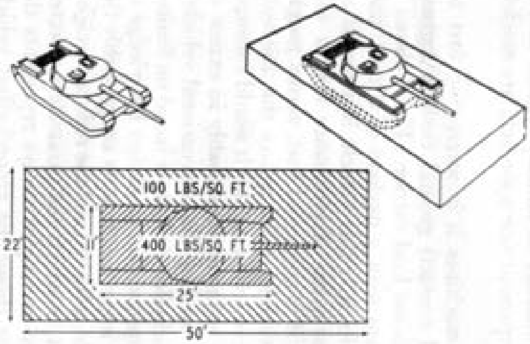


Fig 1(a). 45 ton tracked vehicle.

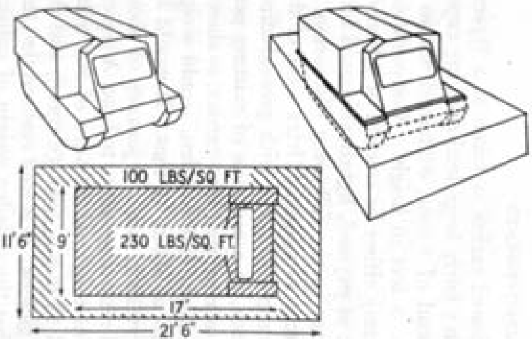


Fig 1(b). Tracked carrier—5 ton payload.

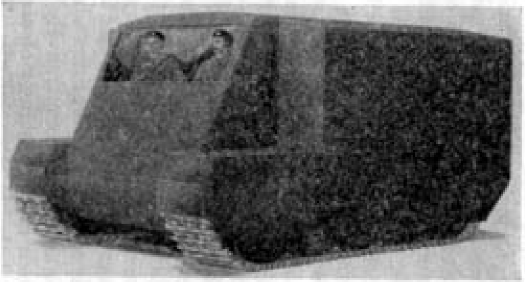


Fig 2. Conventional tracked vehicle—5 ton payload.

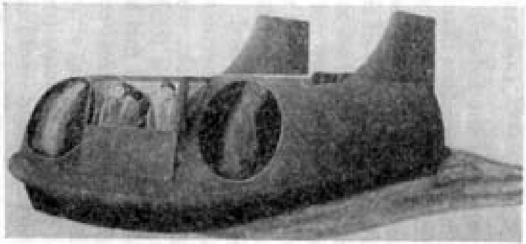


Fig. 3 Ground-effect vehicle—5 ton payload.

Military use of ground effect vehicles 1a & b 2 & 3

tive approaches, first an improved load carrying vehicle and second an improved reconnaissance vehicle, will be examined.

Logistic Vehicle Improvements

If supply of the fighting group mentioned earlier is taken as a typical problem, this suggests a basic vehicle with a fairly large load-carrying capacity, for example a typical military payload of 5 tons, contained within a volume of about 12 × 8 feet in plan × 3 feet in height. Conventional military logistic vehicles of this capacity may either be tracked or wheeled, and either unarmoured or, at the expense of payload, lightly armoured but, as these distinctions are not of importance in the following discussion, a tracked unarmoured vehicle will at this stage be assumed; later some of the problems in selecting wheels or tracks for possible use with ground-effect machines will be discussed. Consider then, as a criterion of existing performance, a typical conventional tracked, unarmoured load-carrier, as shown in Fig. 2. This vehicle, when fully equipped but unladen, would weigh about 9 tons, making a total laden weight of about 14 tons. It would be capable, on its normal fuel load, of undertaking, laden, a journey of about 100 miles over rough cross-country and of returning empty to base. A typical time for the round trip across country for this total distance of 200 miles would be about 16 hours (that is around 12 m.p.h. average speed) and the total fuel consumed would be about 120 gallons. It is well realised that this performance is unspectacular and also, that the unladen weight of military vehicles is high; both, however, should be viewed against the background of the operating conditions shown earlier (in the film). These points are both emphasised because, although present vehicles, by the use of new techniques and materials, will continue to improve, the increased performance, particularly under extreme conditions, and the weight reductions, are unlikely to be other than marginal, and new approaches to military logistic movement, of which ground-effect machines represent one approach, are needed to achieve any major mobility gains.

To assess the potentialities of these machines it is interesting first to evaluate a pure (that is, without ground contact) ground cushion logistic vehicle as a replacement for the conventional load carrier. Fig. 3 shows a schematic design for such a vehicle, again with a payload of 5 tons, and operating at a ground pressure of 100 lb./ft.^{2}; this vehicle is assessed as weighing about 7 tons unladen, or 12 tons laden. Performance figures will be discussed more thoroughly later, but it is suggested that, across rough, although reasonably flat, country, this vehicle could reduce the 200 mile round trip time from about 16 to 7 hours; in achieving this it would consume a fuel load which, although not easy to estimate, is probably in excess of 250 gallons (that is more than twice that used by the conventional vehicle). The heavy fuel consumption of the ground-effect vehicle is based on limited data and further, it may be subject to improvement as design knowledge of such machines increases, so that the more important aspects are probably the greatly reduced journey times which can be achieved and the reduced weight. These are shown comparatively in Fig. 4, in which the parameters selected are such that the highest of each pair of rectangles always represents the most desirable characteristic. The figure shows the ground-effect vehicle to have a slightly better payload/loaded weight ratio, a much higher speed across country (as indicated by the improved ton miles/hour value) but an appreciably heavier though rather ill-defined fuel consumption. These improved values are considered to be possible because neither the vehicle nor the crew should be subject to such violent accelerations, on the assumption (still to be established) that the ground-effect vehicle will smooth the cross-country ride. A point of equal importance in reducing journey times shown on Fig 5 is the *continuity* of motion achieveable over rivers, soft ground and rough ground. Thus the pure ground-effect vehicle gives a clear indication of the military value of ground cushion application but, as a military logistic vehicle it is unlikely in itself to be satisfactory for three reasons:—

(*i*) it is unsuited to operating in limited spaces, for example in road traffic, both because of its comparative lack of manoeuvrability and its large plan dimensions;

(*ii*) its hill-climbing ability will never be adequate, noting that, for a controlled climb (or descent) of even a one in 3 slope, an additional forward (or reversed) longitudinal thrust approaching 10,000 pounds is required;

(*iii*) its obstacle-crossing capability, in terms of the obstacles shown in the film, is unlikely to be adequate.

It is clear that these disadvantages must be avoided; Fig. 1(*a*) has already shown the order of dimensions of the skirt to be placed around a logistic vehicle to reduce the cushion pressure to 100 lb./ft.^{2}, and this suggests an alternative approach shown in Fig. 6, the variable ground-pressure vehicle with collapsible skirts. This illustration, largely self-explanatory, shows a vehicle which always maintains ground contact through its tracks, but which has the facility of using the ground cushion to vary the load on the tracks to suit the conditions of operation. It should however be emphasised that the design shown, although a possible interim solution, still has military disadvantages associated with the relative bulk, the possible fragility and the need for erection and stowage of the cushion-generating surround. It is visualised that a vehicle of this type could operate as a conventional vehicle, with corresponding fuel economy, over roads and moderate cross-country but that over severe cross-country or ground of low-bearing pressure, such as, say, marshland, the ground-effect capability would be adjustably operated to give some smoothing of the ride and to prevent sinkage, while always leaving the tracks in contact with the terrain, so that manoeuvrability, stability, and possibly traction, may be satisfactorily achieved by ground contact, although, as discussed later, for traction a limited aerodynamic force may be advantageous in some situations. Finally, for river crossing the full ground-cushion effect could be utilised; even for a vehicle with an inherent swimming capability this river-crossing feature could be very advantageous, because, as shown in Fig. 7, the vehicle should ride much higher in the water, with a corresponding reduction in the important problem of exit from the far bank of the river. There are at present some uncertainties in this; working at high cushion pressures for land use makes it difficult to assess the equilibrium height and the stability of the vehicle above water, and equally, the effect of the large hole in the water beneath the vehicle when approaching a shallow bank is not known. However, a vehicle designed in this manner should have, in addition to water-crossing ability, the capability to cross at a reasonably high speed many types of surfaces which, because of their low-bearing pressure, would be impassable, or, marginally passable, by normal vehicles; it should also have a higher cross-

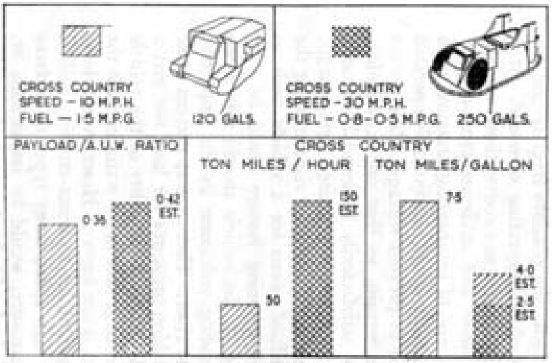


Fig. 4

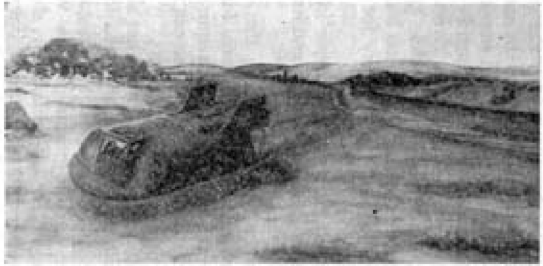


Fig 5.

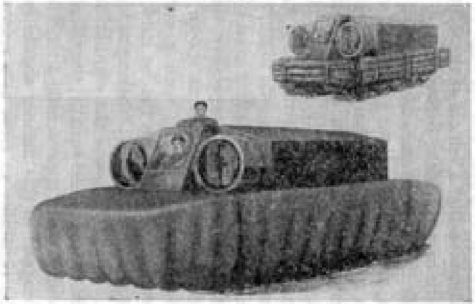


Fig 6. Variable pressure ground vehicle—5 ton payload.

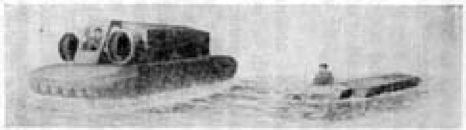


Fig 7. Water level comparison. Variable ground pressure vehicle, conventional load carrier—5 ton payload.

Military use of ground effect vehicles 4, 5, 6, 7

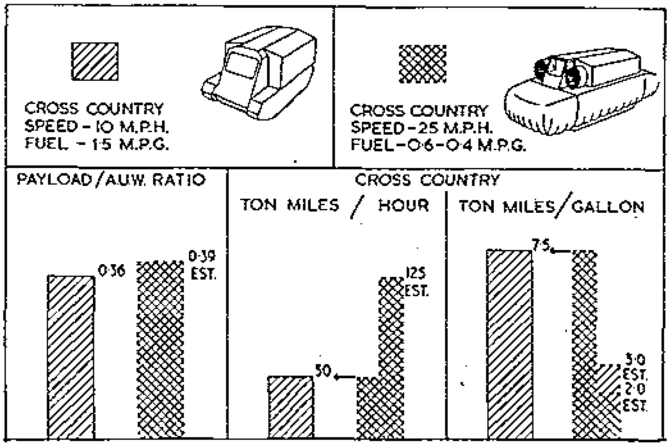


Fig 8.

country speed over difficult terrain to the extent that the vehicle ride can be smoothed by ground effects, but it will combine this with the military vehicle's capacity to tackle steep slopes, to surmount obstacles and to extricate itself from difficult terrain situations. Furthermore, on this reasoning, and subject to experimental confirmation, it should be possible to offset some of the additional "dead" weight of the ground-effect equipment by an overall lightening in the vehicle design, since the higher cross-country stresses in the suspension system should be reduced by "ground cushioning". The vehicle design must, however, be sufficiently robust or resilient, particularly in a longitudinal direction, to accommodate the shocks due to striking unexpected obstacles at speed, and in view of the many conflicting requirements a final weight is difficult to assess.

Figure 8 shows a comparison with the original load carrier; the comparison shows similar payload/all-up weight ratios, but, across country the vehicle's dual capability is illustrated; thus, without the ground cushion (over suitable ground), it can have a similar performance, and fuel consumption, to the conventional vehicle, but, with ground cushion aid, it can achieve a much higher performance, though with a heavier fuel consumption. This dual capability is, of course, lacking in the pure ground-effect vehicle considered earlier.

Some further points on this approach may be noted: the weight saving which might be associated with any scheme is, in itself, of considerable importance, because of the general requirement for air transportability of military vehicles. This type of vehicle should be transportable in tactical supply aircraft, which means that, as a rigid structure, it will be limited to a width not exceeding about 9 feet (which is fairly similar to the desirable figure for unrestricted road usage); although it is apparent that this is unlikely to be achieved at present and, while the problem is less serious for air transport, since detachable side members could be used, this order of width *as a rigid vehicle* should remain a design aim, since the rigid construction will greatly facilitate the movements between roads and cross-country normally associated with military transportation.

This outline is now sufficient to indicate the author's ideas of the broad lines of approach which might lead to an improved, and attractive, military logistic vehicle; however, before this, or any, ground-effect vehicle can be visualised for military ground use, a number of general problems require to be investigated. In view of their generality these problems are deferred until later.

Reconnaissance Vehicle Improvements

Consider now a vehicle for a different military role, namely reconnaissance. A typical current example is the Ferret, which is a vehicle with a low military payload of around half a ton, consisting largely of two crew members and radio equipment, carried in a lightly armoured structure, which is sufficient to provide protection against small arms and shell splinters; the laden weight is about 4½ tons, so that the payload/all-up weight is about 0.11. The vehicle has a good cross-country performance but, because of its higher density, due largely to its armour, it cannot swim inherently. Also, in comparison with the earlier unarmoured logistic vehicles values of 0·36 to 0·42 the penalty of even light armour is clearly reflected in the Ferret's payload/laden weight of 0·11. Although frequently fitted with a machine gun this is not primarily a fighting vehicle; its reconnaissance function is to operate in forward enemy areas in order to obtain and return with information on movements and positions. In this role, two desirable features may be noted; first the ability to move unobtrusively and silently is of importance, and it would clearly be of value to be able to surmount natural objects, such as, for example, hedges and road blocks, as well as to enter, cross and emerge from water obstacles; second, while an armoured hull is an asset it may be an acceptable compromise for reconnaissance to reduce, or eliminate, the armour protection in order to achieve greater mobility and manoeuvrability.

This question of deleting armour is a difficult one on which to comment; it is probably an inevitable initial starting point for ground-effect vehicles, but while it could be acceptable for reconnaissance, it would undoubtedly limit the vehicle's alternative roles. For example, internal security roles are well met by the Ferret; in this case extreme performance is not necessary and light armour is essential. The point to observe is that, while it is a convenient assumption for discussion purposes, no military vehicle is in fact designed for a single role, and the design emphasis varies with the type of operation. It may be premature to complicate the application of new techniques with such problems, but they are not ones which can be indefinitely overlooked.

Returning now to the reconnaissance problem, a simple ground-effect machine is unlikely, as previously, to be an attractive solution; for example it is difficult to visualise it moving unobtrusively and silently in enemy territory and again, as previously, a composite solution seems to be the most attractive starting point; the design aims in this vehicle, however, are somewhat different from the previous example. The vehicle is designed first to have, as a vehicle, an extremely good road and cross-country performance, to be achieved as silently as possible. This means a vehicle of rugged construction with four-wheel drive. Given a ground-effect capability it will tend to be used much less frequently than in the logistic vehicle because of the associated problems of noise and dust, and its use will be to achieve progress where this would otherwise be impossible. Thus, even allowing for the water and soft ground capability conferred by the ground-effect addition, further justification for such complication seems desirable, and might be found in some form of limited vertical obstacle crossing capability. The nearest comparison to the type of performance visualised is in the cross-country capability of a horse and rider, and if the vehicle can be made to jump by means of a storage system where energy can accumulate slowly, but be released rapidly, the solution need not be unduly complex. Further, in contrast to the horse, it appears to be possible to visualise a solution in which the jump can be made either from land or from water. As in the previous example it is not proposed to elaborate on this solution, but to give some idea of the sort of jumping capability—admittedly more extended than that of the horse— which would undoubtedly give a very real increase in the cross-country mobility of the reconnaissance vehicle, while restricting the noise associated with these manoeuvres to periods of very short duration. Fig. 9 shows a typical hedge obstacle, with an adverse landing condition and Fig. 10 a simple anti-tank ditch obstacle. The ability to clear such obstacles is the type of increased mobility which might justify the elimination of the armour which the solution almost certainly assumes; it might still be possible to provide some slight body armour as protection to the crew, but the order of protection possible will be much lower than in current reconnaissance vehicles.

Returning to the jumping capability it may require some slight further explanation as to the reason for specifying these rather limited obstacles. It is this: if the complexity associated with ground-effect motion is to be incorporated in a reconnaissance vehicle at the expense of armour protection it must, as already stated, provide a greater mobility increase than, say, the ability to cross water obstacles, which could be accomplished in any case by removing the armour from a conventional reconnaissance vehicle. A jumping capability could provide this increase, but unless the obstacles are of a limited height, such for example as typical hedges, from which it is estimated that a failure of the lifting system could occur without undue risk of serious crew injury, the design would be further complicated by the general A.P.970 requirements of safety in airborne flight, such for example as the requirement that no single failure of a component should endanger the crew safety. This could imply duplication of, say, lifting engines, with corresponding increases in complexity, weight and cost. It also hoped that the limited flight duration required to cross the specified obstacles might minimise, or avoid, the complexities of auto-stabilisation in the vehicle design. It is clear, however, that any further investigation of such points will lead to consideration of the relative merits of free-flight machines and ground-effect machines for these various military duties; this, while a topic of considerable military interest, is really outside the scope of the present lecture.

Thrust and Power Requirements

To appreciate more fully the ground-effect problems of military vehicles some brief notes on the theoretical derivation of the numerical values used in the logistic load-carrier will be mentioned; many of the derived arguments are generally applicable to ground cushion vehicles and, although they are based on simple jet-curtain and plenum chamber formulae they are quite adequate to indicate orders of magnitude; it is, however, equally true that actual values can only be derived from detailed vehicle design. In this

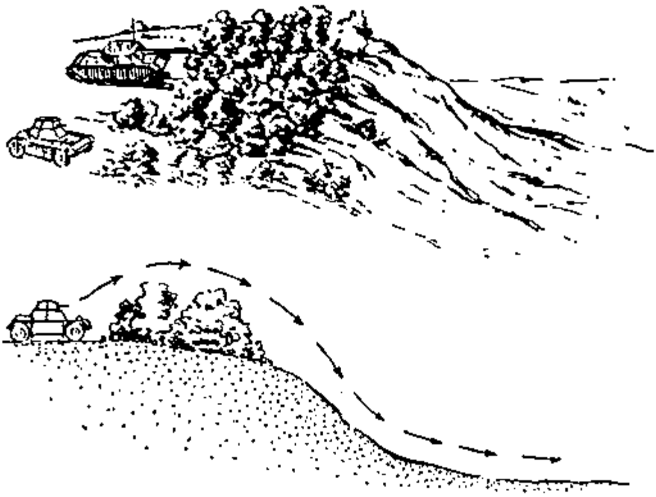


Fig 9. Typical valley obstacle.

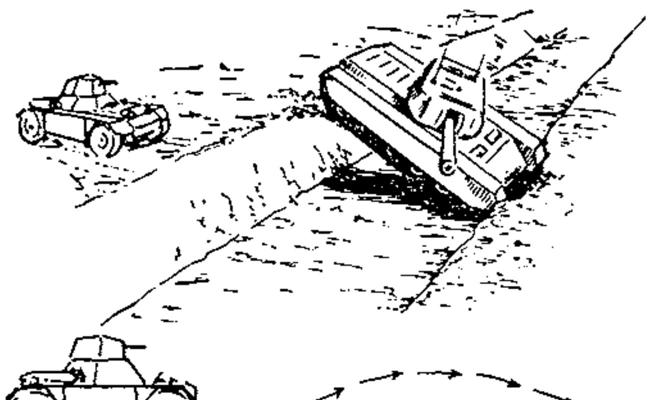


Fig 10. Anti-tank ditch obstacle.

theory, stabilising air and general aerodynamic stability are not considered, but it is to be noted that, except over water, stability from the tracks is visualised.

Consider then the tracked ground cushion military load-carrier with an overall weight of about 12 tons; it has already been shown that cushion pressures much below 100 lb. per square foot are unlikely to be useful in military vehicles and that the belly clearance over rough country must be high, at least 12 inches. The power required at this cushion pressure for jet curtain sealing to a hover height of 12 inches is shown in Fig. 11 to be at least 2,000 h.p.; this is clearly, on a 12-ton vehicle, completely uneconomic and makes essential, for military vehicles, some form of skirt sealing, associated with sufficient skirt flexibility to pass freely over obstacles. Assuming flexible skirts, the relationship of power and hover height (that is the free space below the skirt *while retaining a belly clearance of at least 12 inches*) is also shown in Fig. 11: the relationship is linear because a constant ratio between hover height and jet curtain thickness (h/t_0) has been assumed; there is some practical confirmation that the assumed value for h/t_0 of 3 is of the correct order of magnitude. The advantages of operating at low hover heights (*i.e.* low skirt clearances) are quite clear and there appears to be no reason why the flexible-skirted land vehicle with tracked ground contact for stability, and traction should not operate at a very low nominal skirt clearance; at say, one inch hover height, with an associated curtain thickness of one-third inch, the power requirement of 150/200 h.p. into the fan begins to appear practical. It is also of interest that the jet velocity which, because of its dust-raising and ground erosive properties will be an important parameter over land, is a constant at any point on either of the lines shown, and is approximately 270 feet per second for the lower (theoretical) line. The second curves show the alternative plenum chamber type of sealing; it is well established that this is less efficient than curtain sealing and even at low clearances the power differences are clearly substantial, but, even so, careful consideration of the relative design simplicity of the plenum chamber approach is undoubtedly necessary in any practical design. The other important variable, the air exit velocity also seems to be about the same order of magnitude from the plenum chamber; in the present evaluation it was 290 f.p.s. for the lower (theoretical) line.

Two other points will be illustrated for use in the generalised discussion later; first, as shown in Fig. 12, at 30 m.p.h. with the proposed one inch skirt clearance, both the aerodynamic drag force and the momentum drag force are extremely small, compared with either the vehicle's own rolling resistance or with the effect of small slopes; it is difficult to estimate the rolling resistance of running gear specially designed for a vehicle which will be supported over rough going on a ground cushion, but it may be that the best values for a tracked vehicle will remain undesirably high; certainly the rolling resistance values shown are more likely to be achieved by a wheeled vehicle, but this is a problem which requires practical evaluation, and will be discussed later. The required values of propulsive thrust on the figure suggest that aerodynamic thrust from a small engine (*e.g.* the thrust from the Viper engine as used in the S.R.N.1 is illustrated) could provide an adequate reserve for vehicle acceleration and for climbing slight slopes. These same values are shown to a different scale in Fig. 13, which illustrates that the thrust required to propel the vehicle up the whole range of slopes encountered by

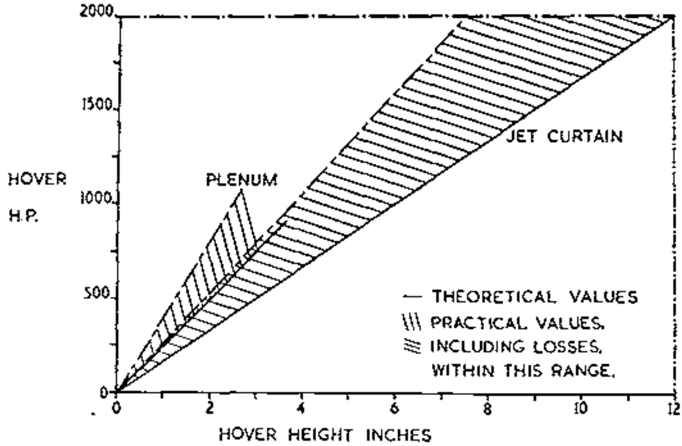


Fig 11.

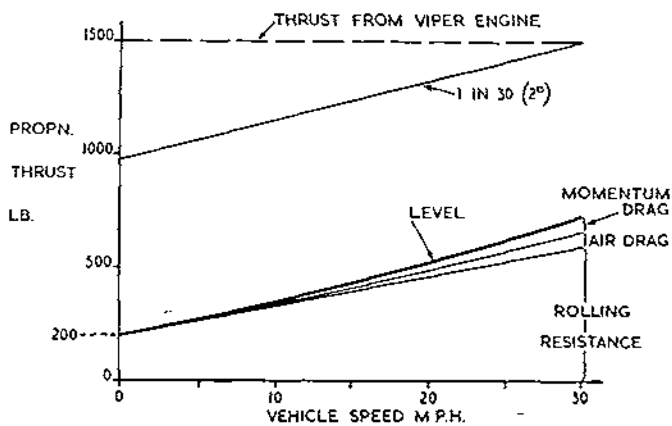


Fig 12.

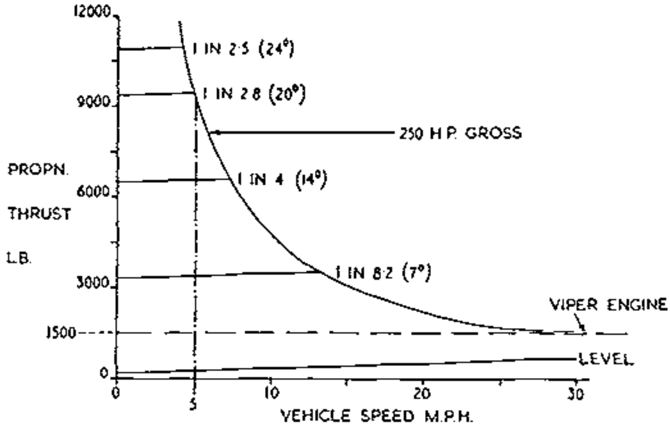


Fig 13.

military vehicles, reaching values in excess of 10,000 lb., is well outside the practical range of aerodynamic thrust, and can be produced only by interaction between the vehicle's track (or wheels) and the ground. The figure also shows that if the traction for hill climbing is produced in this manner and assuming a typical installed power of 250 b.h.p. at the engine this engine power will severely reduce the vehicle's hill climbing speed, *e.g.* the vehicle speed up a 20° slope would be about 5 m.p.h. These points are discussed further at a later stage, but it is clear that, with or without ground cushion utilisation, the steep slope climbing speeds of military ground vehicles will always remain low.

It will be appreciated that the designs outlined are only typical examples of ground-effect application in the battle area and there are undoubtedly, in this very new field, other possibilities, for example, a ground cushion supported stretcher for casualty evacuation (Fig. 14) is being investigated, again in an endeavour to exploit the ride-smoothing capabilities of the ground cushion. The illustration shows the stretcher being manually controlled but it can also be towed, at higher speed, behind a vehicle.

Fig 14.

Practical Problems

Practical problems already discussed which affect the military use of any overland ground-effect vehicle are:—

(*i*) to establish whether in fact the ground-effect vehicle, operating with some form of ground contacting running gear, will be capable of traversing rough ground at high speed;

(*ii*) to establish whether the variable ground pressure principle will ensure a greater continuity of motion across hard ground, rough ground, soft ground and water;

(*iii*) to evaluate jumping obstacle-crossing capabilities.

Arising from these is the further problem as to whether the running gear, which must still be suited to driving the vehicle over roads and smooth terrain (without ground cushion assistance), can be lightened and the rolling resistance reduced in comparison with a conventional running gear designed for all terrain conditions. Such data will only be obtained by means of practical field trials, but it is possible to see the problems which must be solved, and these will be illustrated by reference to the load carrier.

Consider first the pure ground cushion vehicle, *i.e.* with no ground contact and aerodynamic traction; it appears reasonable to assume, even at high speed, that this vehicle will ride smoothly over broken ground where, say, the main obstacles are boulders of less height than the ground cushion and of appreciably less length than the vehicle length; it is, however, possible first that the vehicle will be excited to damped natural oscillations on its air cushion, with a rather indeterminate damping factor, and second that, because of the military requirements for large ground clearance, small plan dimensions and high cushion pressures, stability on the ground cushion particularly in strong or gusting winds will be a difficult problem. (This latter problem must, of course, be solved for water crossing but in this case additional stabilising buoyancy aids may be introduced.) For both these reasons it is therefore probable that some stabilising contact with the ground over rough terrain is required; ground contact is also certainly required to obtain an acceptable standard of vehicle manoeuvrability and may be required, depending on the circumstances, to provide vehicle traction. Such contacting devices must necessarily be attached to the vehicle through resilient suspension members but, even so, their contouring motion over rough ground will produce reactive forces on the vehicle whose tendency must be to degrade the quality of the ride. The requirement therefore is for a traction/ steering/suspension system which is suited to normal, non-ground cushion use on smooth surfaces, partial ground cushion use over soft surfaces and full ground cushion use over water and which, for ground cushion use over rough ground, can be adjusted to minimise the reactive forces on the vehicle. Such a system can be visualised in broad outline; if rolling resistance is to be minimised the system would tend to consist of supporting wheels of lightweight construction (*i.e.* of low unsprung weight), rather than tracks, such wheels to be steerable and driven, preferably regeneratively for braking, and attached to the vehicle through a long travel suspension, such as a hydropneumatic system, whose rate could be adjustably varied from a stiffness adequate for normal smooth going without ground cushion support, to a greatly reduced value for rough ground crossing with cushion support. The traction and braking available from the wheels would vary with the suspension loading and it is visualised that this traction, for many off-road conditions, could be replaced by aerodynamic traction (*i.e.* by propeller or jet forces) to an extent that, for rough level going, the wheels would not be used for traction but only, under light loading, for stability and manoeuvre. As an example, from the figures already shown, an aerodynamic thrust of about 1,500 pounds should, without ground assistance, give a typical logistic vehicle a speed over rough level ground, or water, of about 20–30 m.p.h. For hill climbing, noting that a 1 in 3 slope will need an additional thrust of about 10,000 pounds, this aerodynamic thrust will be completely inadequate, and it will be necessary at the expense of both the quality of the ride and of a reduction in speed, to obtain the additional thrust from ground traction, by suitably increasing the suspension spring rate and reducing the cushion pressure.

While this appears to be an elaborate system it is one which, if the outstanding problems could be solved, would offer a very real advance in high-speed military cross-country mobility over every type of surface including rough ground, mud, snow, swamp and water. This high-speed mobility, however, does assume in addition a vehicle of adequately robust, or suitably flexible, construction to cross-country containing the types of large obstacle shown earlier.

Some slight amplification of the selective use of tracks or wheels for military vehicles can be usefully made at this point: on soils of low bearing pressure (and frictional strength) tracks, because of their large area of contact, will minimise sinkage, thus preventing vehicles bellying and losing traction, and will also provide maximum traction in comparison with wheels. They achieve this, however, at the expense of a high built-in rolling resistance, which, again in comparison with a similar wheeled vehicle, considerably increases the tracked vehicle's fuel consumption and reduces its road-speed. In the vehicle system outlined above, tracks should be unnecessary in all cases other than the severest hill-climbs, as the ground cushion will minimise sinkage and the combination of aerodynamic and ground traction, with the exception quoted, should be adequate for most conditions. There is, however, a further qualifying factor, namely obstacle crossing; a tracked vehicle, because of its high idler wheel, will cross larger vertical obstacles and also, because of its track length, wider ditches than an equivalent wheeled vehicle; this is not necessarily considered to be a sufficient advantage to warrant the use of tracks, but obstacle crossing is of importance and should be given careful consideration in any design.

It will be noted that most of the suggested military applications of ground-effect use this as an intermittent, rather than a continuous, aid; although direct experience is at present lacking it is considered that a ground-effect vehicle will tend to reveal its battlefield position rather conspicuously from a combination of the moving dust-cloud it forms and from the extremely high noise level associated with its progress. These are serious disadvantages on which further experience is desirable but, it is felt, they can be minimised by discriminatory intermittent application of the ground-effect facility. This will introduce some further technical problems: if the facility is used only to assist under extreme conditions, for example, a vehicle may find that it is bogged under normal vehicular control and can only extricate itself by ground effect aid. It is therefore important that the air exits are not blocked when the vehicle is deeply embedded in soft ground, or mud, to an extent which will produce stalling conditions in the fan; in this condition excess thrust for extraction may also be required.

Again, the earlier theoretical assessments suggest that the air will have a velocity of around 300 f.p.s. at ground level. This is high compared with the downward velocity of the air through helicopter blades—generally less than 100 f.p.s., but low compared with the supersonic gas velocity from direct thrust VTOL engines. The problem to be assessed is the effect either on wear of the engine or erosion of the fan blades, of the cloud of dust, mud or small stones which may be raised by the action of high velocity air on the ground. The problem is illustrated in Fig. 15, which shows the extensive disturbance caused by a helicopter, of about 2½ tons weight, that is about the same weight as the proposed reconnaissance vehicle, when hovering over desert sand, with a downward air velocity of 45 f.p.s. generated at a height of about 10 feet above the ground; the proposed ground-effect vehicles will generate air velocities at ground level of around 300 f.p.s. Note the indications of recirculation in the airborne sand pattern. There is some suggestion from VTOL experience that during take-off an aircraft may operate in a region of comparatively clear air surrounded by a cloud of dust and combustion products of possibly 100 feet in diameter; if this also occurs at the lower air velocities of the ground-effect vehicle, it may be that the forward movement of the vehicle, assisted possibly by some deliberate longitudinal asymmetry in the sustaining air flow pattern, can still maintain a clear air region ahead; there is already some experience over water of spray deflecting techniques to maintain visibility. If, however, this external dust cloud should recirculate through the engine and fan, then engine air supply, engine wear and blade erosion could be significant problems. On a smaller scale, the dust erosion of cooling fans is a familar problem in military vehicles and Fig. 16 illustrates an example of such erosion; the scale shows the original line of the fan blade leading edge. This suggests that a problem of some magnitude may exist with ground-effect vehicles and also, that internal recirculation of jet curtain air, even with its attractions of increased efficiency, may not be a useful device on these vehicles. Externally recirculating dust will also settle on the vehicle and the design must avoid surfaces where dead loads can thereby be accumulated. Dust is not the only problem in lifting-vehicles; additional dead weights of mud can also be accumulated, and in an experiment on a 12-ton military vehicle an additional half ton of mud was measured after a few hours' driving. These effects may be of the greatest importance on vehicles with small available payloads, such as the reconnaissance vehicle.

It is not yet clear whether ground-effect machines will be powered by piston engines or gas turbines. In either case, efficient air cleaners for operating in dusty conditions will be necessary, but if recirculating dust exists, the air cleaning problem may be aggravated for the gas turbine by the larger quantities of air it consumes, even though the efficiency of air cleaning which it demands is reduced. There is another point about the use of a gas turbine as the lifting power source, namely that, in the solutions visualised, it will never run for lengthy periods and, in practice will be operated on a cold start—short run—stop sequence; whether the thermal shocks associated with this continual sequence of cold starting will result in fatigue problems, or in high rates of wear, is a further problem for evaluation.

Another problem is the tendency for these vehicles, in comparison with existing military vehicles, to be what can only be described as dimensionally cumbersome. Overlaying skirts, collapsible or otherwise, may represent a necessary interim stage of development of these vehicles, but they are likely to be militarily unattractive, both because of their bulk and their potential vulnerability to damage by obstacles. This suggests that there are marked advantages in operating at the maximum possible cushion pressures, with particular reference to achieving a reduction in overall width to 9 feet or less, which is a convenient dimension both for air transportability and for operating in normal traffic on roads.

Finally, on the problems of cost, reliability and maintenance which face any new developments, it may be noted that, for example, forward-area load-carrying involves large numbers of vehicles and, because of this, their individual cost is important. As an order of present cost a typical high performance, swimming, 5-ton load carrier might cost in production around £12,000. Similarly, with a relatively small amount of maintenance, done

Fig 15.

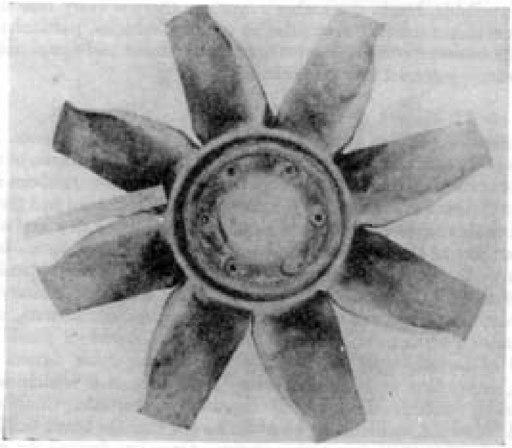


Fig 16.

under field conditions, military load carriers can operate reliably for long periods, and against this background, and the current background of military experience of, say, helicopters, which require a completely different order of maintenance, the advantages of a load-carrying vehicle capable of higher speeds across country but requiring possibly much more field maintenance are not easy to assess.

Thus, these are the general problems which require evaluation before any overland ground-effect vehicles can be specified for military use. If the problems can be satisfactorily solved, they indicate that the cross-country speed of many military vehicles, over most terrain, could be increased from about 12 m.p.h. or less to around 30 m.p.h. and that much greater continuity of progress against a variety of natural, and artificial, obstacles could be achieved, particularly by the leaping vehicles. The solutions, however, will leave the military vehicles in contact with, and therefore still dependent

Military use of ground effect vehicles 15 & 16 - 278 upon, the ground surface, with the associated implication that their forward speeds will be unlikely to exceed the figure quoted, and will be well below it when ascending steep hills. This may, therefore, seem to be a relatively modest gain in military mobility, but it has every appearance of being a realistic one and further, is one which may well be achieved at an acceptable level of vehicle complexity (and cost). It probably approaches the final limit of cross-country ground progression (and is, of course, in its ground cushion and jumping aspects, already partially airborne); the next military forward area stage, and one with which the ground-effect vehicle will inevitably compete in the future, is to be independent of the ground by the application of free-flight helicopter or VTOL techniques. These techniques offer still greater mobility in association, however, with greater complexity—and cost. It would be premature on present knowledge to attempt a firm comparison between all these various techniques until more knowledge of them is available, but in the author's opinion, there is every reason to continue to evaluate military groundborne cushion vehicles, particularly since it is in the outlined compromise between achievement and complexity where their greatest potential may be achieved.

DISCUSSION

Professor A. D. S. Carter (Royal Military College of Science, *Fellow*): There was little doubt that the Army required a greater degree of mobility than was available at present, and conventional vehicles were about reaching the limit of their development. He knew that Mr. Coulthard had given great thought to this subject and the solution he offered was a new and attractive one. He thought Mr. Coulthard had been forced, however, to his final conclusions by the limiting dimensions fixed for the vehicles, particularly the width of about 8 to 9 feet. Some calculations at the Royal Military College of Science, which did not differ greatly from other calculations, indicated that optimum sized pure hovering ground-effect machines would carry a payload of something of the order of 100 tons. Other figures differed slightly, depending on the assumptions taken. Such a vehicle would be considerably outside the physical dimensions that Mr. Coulthard had allowed. It would, incidentally, be of such a size that the hover height would provide adequate obstacle crossing ability. Once one limited the sizes, one ran into difficulties. He was sure that although Mr. Coulthard had made a strong case on other grounds, such as stability, climbing power, and so on, for the variable ground pressure machines shown in the lecture, the major reason he adopted a dual ground-effect/road wheel vehicle was the width limitations. This prevented full utilisation of the ground-effect principle. He was a little doubtful whether Mr. Coulthard was getting the best or the worst of both worlds. The ground-effect machine had one thing in common with all aircraft in that every pound of structural weight was a pound less payload—and yet a dual system was proposed. When arming these vehicles for internal security purposes the problem was magnified. Would Mr. Coulthard elaborate slightly on the armour penalties he would allow in order to get increased ground clearance effect and mobility in the purely ground-effect regime?

In the lecture the leaping machine was discussed and, very quickly, auto-stabilisation. It seemed to him to be the 64,000 dollar question. If, as stated in the paper, these vehicles were inherently stable during the leap then undoubtedly they would be attractive in all respects. If one had to stabilise them with standard techniques then they were fast approaching the free flight vehicle.

On noise and dust, the latter seemed to him to be the more significant, giving rise to technical and operational problems. Curtains and such like would no doubt help but this was a serious problem for which he hoped Mr. Coulthard had possible lines of research. The re-circulation distinctly visible in the photograph of the hovering helicopter seemed a rather ominous sign.

He had enjoyed the lecture and agreed that more work must be done on this topic. Mr. Coulthard had presented a novel solution, feasible, and attractive, but which would probably need considerably more research before they could be sure that it was a practical proposition for the Army.

Mr. Coulthard: Large hovering craft were specifically excluded from the lecture to concentrate the theme on the potential of the ground-effect principle at current military vehicle dimensions; it was not intended thereby to imply lack of military interest in these larger sizes, which had already been adequately described in technical publications and earlier lectures. For the small sizes considered the suggestion was that their greatest military potential would be associated with vehicles which obtained some, or all, of their traction and support from the ground rather than with fully airborne vehicles; no attempt was made—nor would it be made on present knowledge—to extrapolate this conclusion to 100-ton hovering craft.

Armour would impose a heavy performance penalty, and would be considered impracticable at this stage; the decision between increased performance and reduced armour would eventually be taken by the military staff, and the internal security role was mentioned as being the one most likely to demand armour rather than optimum performance.

There were no current answers available to the other points raised by Mr. Carter, but the serious nature of all these problems was appreciated and agreed.

G. Ratcliffe (Handley Page Ltd., *Assoc. Fellow*): Could the lecturer say why he appeared to have taken most of the parameters to their uneconomic extreme? As had already been hinted, the limitation of spanwise dimension to 8–9 ft. was serious as the operational height, and with it the sensitivity to obstacles and uneven ground, was directly related to this function for all reasonable variations in power and aerodynamic efficiency. He believed it was true that most of the work published on the subject had been tied to higher ratios of spanwise dimension and higher ground clearances, where the American approach tended towards variable geometry and consideration of the relationship between road use and cross country performance. To take full advantage of variable geometry something more than the small increases available from flexible inflated skirts was required. Folding and retractable "side wings" had been considered in the United States. These might double the effective "span" (b) and permit hover and cross country heights high enough to avoid the necessity for the vehicle to circumnavigate frequently occurring obstacles, such as hedges, or negotiate steep gradients at the very low speeds quoted. Heights of 0·5 to 0·6 b should be possible using "Take-Off" power rating or stored energy.

Could the lecturer explain how wheels or to a lesser degree tracks, could be helpful for the problem of ground adhesion in that the ground pressure of those devices was fundamentally important in the steerage response or tractive effort which was obtained from them? Would they not need to be supplemented by aerodynamic thrust forces to maintain effective control and, in the ultimate, become little more than a signalling system?

MR. COULTHARD: As mentioned in the previous reply the lecture was directed towards evaluating the role of the ground-effect principle applied to small military vehicles and, even in this field, it was possible, as the questioner indicated, to produce a variety of solutions depending on the assumptions made. The assumptions of the lecture were that a small vehicle would be unlikely to carry an additional power unit much in excess of 200/310 h.p. for hovering, with possible energy storage for occasional boost, and that even this would only be used occasionally, *e.g.* for crossing very difficult ground or obstacles, because of all the increased fuel consumption involved; the film was intended to support this argument by indicating that robust military vehicles could already traverse a wide range of terrain. In view of this incidental use of the ground-cushion equipment, considerable emphasis was placed on its robust design and, in the lecturer's view, although an increased structural width would increase the hover height it would be progressively more subject to damage on rough terrain; it was, however, readily agreed that there was scope for much further investigation here to decide on an optimum value. The transient heights possible with stored energy were agreed.

On the problem of the effect of off-loading the tractive members by the ground-cushion this off-loading should reduce the rolling resistance of the vehicle, particularly by reducing the sinkage—over soft ground; under these conditions the reduced traction should be adequate; again this was a problem where work to establish optimum conditions was necessary. Any available aerodynamic forces would contribute to this solution, but the graphs (Figs. 12 and 13) indicated that aerodynamic forces alone were unlikely to provide an adequate ground propulsion system, even assuming some increase in hover height.

R. A. SHAW (*Ministry of Aviation, Fellow*): He wanted to take a point with the lecturer's picture of tractor and hovering vehicle which he thought was an incompatability. Mr. Coulthard envisaged a track system which was softly sprung associated with the curtained support, but he did not think the two went together because, when Mr. Coulthard was talking about a 3-inch clearance height under the edge of the curtain, the curtain itself was notoriously stiff and if the support of the track or wheel system were soft, he was afraid there was nothing to stop the craft settling down an inch on its curtain and supporting the whole of its weight on the pressure system. Still, he agreed that the combination of track and hovering craft was a sensible one for a manned vehicle; he had no great hopes of their being satisfied in the Army with these small vehicles with auxiliary air systems, unless they were prepared to go to fairly large systems, but he welcomed this interest from them because he thought they were practical chaps and they needed more people thinking about ground-effect vehicles and the kind of solutions which they would discover by their efforts might not be applicable to the Army, but they might be applicable to the GEM family in general. In the wonderful performance shown by these vehicles as they existed at present, Mr. Coulthard might have defined the boundary condition for them.

MR. COULTHARD: They felt some optimism in finding a useful compromise between suspension stiffness and curtain stiffness; the excessive curtain stiffness suggested by Mr. Shaw had not so far appeared as a serious problem. Regarding the ability to clear 3 to 4 feet obstacles, this was where the jumping vehicle could have an application, possibly more economically than a vehicle with a large hover height, which, for the small vehicles outlined, would need an impracticably large engine to achieve. Belly-clearance, as distinct from the flexible curtain clearance of, say, one or two inches, would always be visualised, for obstacle clearance, as around the current value of 15/16 inches.

MR. SHAW: If one reckoned to build a vehicle to cross unknown ground which had obstacles of about 3 or 4 feet in height covered by bushes, it seemed to him that the only way in which mobility would be achieved of the sort which he intended having was by having large clearance, or a soft substructure at least of that order because otherwise one could not achieve it and the height associated with the speed.

DR. W. CAWOOD (*War Office, Fellow*). *Chairman*: This question of the harmonisation of the two suspensions—air and spring—how much did they know about the ground cushion characteristics? It was said it would be very stiff, but after all it was only like being balanced on an enormous great rubber tyre with an air pressure of one lb./in.^{2}, so it could not be all that stiff, could it?

MR. SHAW: It depended if one included the stiffness of the flexible curtain. . . .

DR. CAWOOD: It was flexible. It had not any stiffness really so far as the vehicle was concerned, had it?

MR. SHAW: It did not suffer any distortion . . . until it made contact.

DR. CAWOOD: He was asking, because if it were as stiff as was said, which rather surprised him, it seemed the last thing to put a stretcher on.

MR. SHAW: It became soft when the edge made contact but until the edge made contact there was a tendency for the pressure to build up.

L. W. ROSENTHAL (Folland Aircraft Ltd., *Assoc. Fellow*): Referring to the Chairman's remarks about the stiffness of the skirt on the stretcher, they had had so many other problems that interactions between the ground and the natural frequency of the vehicle had not received attention, and he suggested that before one started arguments about this kind of problem, they try to resolve some of the others. In Follands they had spent a considerable time in looking into the problem of the overland use of hovering vehicles and had been trying to determine what the parameters were, what softness of ground they were thinking of working over, what kind of holes and obstacles were run across under working conditions. That applied also to the hill climbing problem, where Mr. Coulthard had shown that aerodynamic thrust could not be used very efficiently. They had come to this conclusion some time ago and consequently had studied wheeled traction. They then started to worry about how much traction could be obtained with wheel transmission over very soft ground, and they could cope with gradients. They came to the most convenient conclusion that the steeper the gradient, the greater the possibility that the surface would be hard enough to support reasonable traction. Coming back to Mr. Shaw's point about what happened when one met a hole 4 feet in diameter—were holes 4 feet in diameter likely to be met under the conditions where the hovering system was being used? He would suggest that under most circumstances, the hole might well fill up, at least partially. Would Mr. Coulthard, with his experience of overland conditions, define the capability he needed?

Returning to the dust problem, they had some film showing dust being blown up by the stretcher pallet and also by the GERM, and there was only one word for the problem—"formidable". It was really something to be seen, before there was any discusion on this matter, and at present they themselves had no solution; they were not saying there was not a solution, but, they did not know it. While it might be possible to operate in no wind and head wind conditions, in strong following winds the vehicle became completely enveloped.

Mr. Coulthard had suggested that perhaps 9 ft. was the best width for the vehicle. It did not take long to do a few sums to find out what that meant. A cushion pressure of 100 lb./ft.^{2} gave 0·4 of a ton lift per foot length of vehicle. So, if considering shifting loads of any size, or armoured vehicles, it was easy to calculate the vehicle length. It was possible that cushion pressures over the land could be forced up beyond 100 lb./ft.^{2}, but this would certainly demand a big development programme on the fans and ducting systems. He would like to ask Mr. Coulthard what conception he had of the size of a large, heavy vehicle, to see how he sorted the problem? Also what information could he give on the relationships between soft ground where hovering capacity was needed, and the type of terrain and the slopes associated with it?

Mr. Coulthard: Mr. Rosenthal missed the early part of the lecture, and the film, which endeavoured to define the capability required by military vehicles; on hill-climbing vehicles must certainly be capable of climbing, say, 1 in 3 slopes, and the lecture suggested that, since a 12-ton vehicle would require a propulsive thrust of around 10,000 lb. for this, aerodynamic traction, unaided by ground traction, was impracticable. The sizes of various cushion-supported vehicles were shown in Figs. 1(*a*) and 1(*b*) and these figures were used to discard the heavy tracked vehicle as unprofitable for air cushion support at the present stage of knowledge. On the final question there was little which could briefly be added to the film presentation, which had now been seen by Mr. Rosenthal, on this subject.

A. R. Howell (N.G.T.E., *Assoc. Fellow*): In the first part of the lecture one wondered how Mr. Coulthard kept his engines so small. The fuel consumptions quoted were very much better than those he got by some simple sums, and then only hundreds of horsepower were referred to when he expected thousands. But as the lecture went on he realised how this was done. In the load carrying vehicle presumably they were only operating at 3 or 4 inches hover height, and on one of the other vehicles they seemed to be down to one inch. Now if these figures were accepted, the engine problem was a fairly easy one. They had not got to worry too much about weight, powers were low, and the problems were with things such as the fan, duct losses, air cleaning, noise, etc.

However he could not believe the low power figures. He did not believe one could operate at a few inches. He was assuming, and the film rather convinced him in the first place, that they were talking about one foot and two foot heights, which of course naturally multiplied the powers involved many times. Taking a 9 foot width reconnaissance vehicle of, say, 6,000 lb. weight and 15 ft. length (a loading of 44 lb./sq. ft.) with 1½ ft. operating height, they had just worked out very roughly the total power to be about

1,000 horsepower; if it had to overcome 3-foot obstacles then about 2,000 horsepower would be needed, which was about the value required for a fan lifter for VTOL. Returning to the 1½-ft. operating height, the power was still appreciably more than for a helicopter.

He was not saying that these higher power figures were out of the question, but if required they would result in a change of emphasis towards lightweight engines, aircraft methods of construction, and so on, to compensate for the much larger quantities of fuel that would have to be carried.

MR. COULTHARD: The low power figures, and the associated low clearances for the skirt, were not submitted, at this stage, as realistic, since adequate experience was lacking; their importance was that (viewed in conjunction with the large increase in fuel consumption, compared with conventional vehicles, which even these modest values entailed), unless such figures could be made realistic this approach to increased military mobility (and it was by no means the only approach) was likely to become increasingly unattractive. Of the point mentioned finally, the substitution of a light vehicle with a heavy fuel consumption for a heavy vehicle with a low fuel consumption would be regarded with considerable military disfavour.

G. E. PREECE (*Assoc. Fellow*): Mr. Coulthard had chosen to retain the American description "ground effect machine", derived from the aerodynamic terminology for conventional aircraft. This was to be regretted, since the use of "air cushioned vehicle" would seem to be more apt for these machines, particularly when one was concerned with very high cushion pressures.

The importance of maintaining the absolute minimum clearance between the vehicle and the ground had been emphasised and this in turn implied the use of flexible skirts. For muddy terrains and in water at speeds up to 30 m.p.h. the skirts might be in contact with the ground giving virtually zero clearance. Power requirements then became very much more realistic than Mr. Howell had calculated assuming the use of air curtains. For a personnel carrier, for example, it would appear that loadings of the order of 30 lb./ft.^{2} were possible. This would correspond to a vehicle approximately 6 ft. wide by 12 ft. long weighing just under one ton. Then, by using side plates and flexible curtains to reduce the ground clearance to the absolute minimum, the normal engine horsepower provided in such a vehicle would, in fact, be adequate to form the ground cushion.

The possible advantage in going over minefields with such vehicles had been mentioned. It would not be difficult to devise a mine which could be triggered by variations in air pressure however, and the advantage would be a temporary one only, The final question he would like to ask was concerned with crossing obstacles and he was not at all clear on the flying technique proposed. In the leaping phase was it foreseen that the vehicle was supported on the air cushion or did the initial forward speed carry the vehicle across with the air cushion providing damping of the impact when landing on the landing side?

MR. COULTHARD: The proposed terminology was agreed as being useful. While there could be special cases where lower ground pressures might be useful, as quoted, in the general military application the lecturer would express his opinion, as given in the lecture, that ground pressures below about 100 lb./square foot were unlikely to be useful in military vehicles. In reply to the leaping vehicle question the method of operation would be as phrased in the final part of the question.

D. Lofts (de Havilland Aircraft Co., *Assoc. Fellow*): There might be room for a combined "ground effect" and "walking" machine. He did not know if this had been considered. He had in mind a vehicle with several, say four, separate cushion pads joined by a simple pivoting structure with the main hinge some feet above the ground. The vehicle would travel in the normal manner across flat country like any hovering craft. For hill climbing, gas would be turned off the rear two pads, thus fixing them firmly to the ground. The front pads, still with "cushion" gas on, would be pushed up the slope by, for example, jacks acting on the link structure. The process would be repeated by alternately turning gas on and off the front and rear pads and pushing front and pulling rear pads up the hill via the link structure, *i.e.* the vehicle would "walk" up the hill. This process could be quite rapid. If warranted, particularly severe conditions could be countered by transferring main payload from one set of pads to the other independently of the main vehicle movement. This would enable a suitably designed unit to walk over obstacles. In this case, with the main load concentrated over the rear pads, the light front pads would be lifted over the obstacle, payload transferred to the front pads via the link structure and the rear pads lifted over. The vehicle would then proceed normally.

Dr. Cawood: Curiously enough this had been put forward by the Americans as a possible moon transport. He had read it in a report some time ago.

J. B. Chaplin (Folland Aircraft, *Assoc. Fellow*): On the question of curtains; in this industry anything that would reduce power was attractive and was at once concentrated upon. This happened with recirculation, and it seemed to be happening now with flexible curtains. The point he would like to make was that curtains reduced power by reducing the mass flow required when they reduced the existing gap at the bottom of the vehicle. This would be a disadvantage for crossing ditches since the cushion air exhausted through the ditch and if, as one speaker had suggested, the vehicle dragged its skirts, there was no ditch crossing capability at all. With a very small mass flow a shallow ditch would exhaust the whole of the mass flow and the curtain would collapse. In the design of cross country plenum vehicles, the curtain depth, *i.e.* the flexible part, was determined by the rocks to be negotiated and the hover-height, that was the distance from the bottom of the skirt to the ground, would be determined by the ditches to be crossed.

J. S. Shapiro (Servo Tec Ltd., *Assoc. Fellow*): He wondered if the possibility of a compromise had really been given sufficient thought. He had in mind something like the vehicle with, say, 20 or 30 lb./ft.^{2}. He thought one could get very good low capabilities with powers of something like 1,000 horsepower and that there were definite possibilities there which would bridge a gap in thoughts between the kinds of vehicle they had been shown and the helicopter with its very much lower load capabilities and horsepower and he wondered whether this had been given any attention. There had been a tendency to regard the helicopter as something apparently complex, but, compared with the vehicles which they saw in the film the helicopter was an intricately simple machine.

Dr. H. Roberts (Westlands (Fairey Division) *Fellow*): He would like to do a little mental arithmetic comparison between the helicopter and Mr. Coulthard's vehicle. Assume that one was given £1,000,000 and told one could use it in one of two ways, either by using helicopters or by using Mr. Coulthard's type of vehicle. Considering the helicopter first, for a million pounds, taking a prime cost of £15 per pound all-up weight, one would expect to get something like 70,000 lb. all-up weight of helicopter. For a reasonable sort of range and taking 25 per cent payload one therefore got something like 17,500 lb. of payload. Taking 150 m.p.h., 17,500 lb. of payload was roughly 8 tons, one was getting something like 1,200 tons–m.p.h. as the total work load capability. Taking Mr. Coulthard's vehicle, the figure quoted for prime cost was £20,000. One would get 50 of those to £1,000,000. The average speed would be 15 m.p.h. the total tons carried would be 5 tons per vehicle. The total work load capability was 3,750 tons–m.p.h. or three times what it was for a helicopter. However, one was tied down to all sorts of terrains to which the helicopters were not tied; a large number of comparatively well trained drivers would be required, one would be tied down to a comprehensive system for the logistic support of the drivers, all the fuel carried, all the maintenance. Surely it would be far more worth while to use helicopters, especially as the initial price of the ground vehicle was likely to be much higher than had been quoted so that the advantage in respect of the work load capability of the two vehicles might well be reversed.

Mr. Shapiro: The kind of compromise that he had in mind would make some use of ground effect (in this case, the title of the lecture was more correct as "ground effect", not "cushion"). In order to tie in with the mental arithmetic of Dr. Roberts, he would say that such a vehicle at perhaps the same cost, would have nearly double its payload. So one would arrive at a compromise which would have almost the same obstacle clearing capacity of the helicopter but double the payload.

Mr. Shaw: Mr. Coulthard should not agree with Dr. Roberts' sums. He had been checking them and the ratio was not two to one in favour of the helicopter but three to one in favour of the ground-effect vehicle.

Mr. Coulthard: As indicated in an earlier reply, it was doubted whether ground pressure values of around 30 lb. per square foot would offer sufficient military advantage, particularly in view of the disadvantages—also outlined —of ground-cushion machines; it was this doubt which dictated the values of around 100 lb. per square foot on which the lecture was based.

The comparison between free-flight machines, such as helicopters, and ground-effect machines was considered more suited to a full-length discussion than to a footnote, but, without detracting from the advantage of the helicopter, it undoubtedly would not compete with the military vehicle in its ability to operate day and night under any weather conditions, or in its ability to do so for long periods with only field maintenance.

Dr. Cawood (*Chairman*): He thought this was a fascinating technical field, there were many unknowns and he was quite convinced that the next thing they had to do was get a few of these strange beasts built and try them. A good deal of the performance was straightforward, rather according to Isaac Newton, but the great unknown was in the stability of these things, especially stability during leaping and he did not think they would be able to get much farther until they had a few research vehicles built for trials. They hoped over the next few years to build some of them. On the question of helicopters, he would remind them that the Army did use them, they used as many as they could get. Many were operated by the Royal Air Force, but he was talking now for the Army, and he was sure that they were and would be, the principal users. The Rotodyne for instance, was one of the big load carriers that the Army looked forward to using; but in the battlefield, these things might be shot down. There were conditions, quite apart from the weather, night, and so on, when airborne vehicles, unless they were travelling at very high speed, could not live for long. It was then that he thought the Army came into its own, it had to do its job and had to work below tree-top level and it was on these occasions that the ground/air vehicle would play an enormously useful part in improving mobility and increasing the momentum of a strike.

Some Memories of Survey in Nigeria 50 Years Ago

By MAJOR-GENERAL G. G. WATERHOUSE, CB, MC

IN about 1910 there arose a sharp difference of opinion between the Colonial Office and the War Office as to the value of the maps which were being produced by the Directorate of Survey of Southern Nigeria. One of the awkward questions put forward by the Geographical Section of the General Staff, at that time under Colonel Close (later Colonel Sir Charles Arden Close, KBE, CB, CMG, FRS), concerned the nature of the special geodetic conditions in that Colony which caused some of the rivers to run up the contours. The upshot of the controversy was that the War Office agreed to supply the bulk of the European members of the Survey Department and Major F. G. Guggisberg, CMG, RE (later Brigadier Sir Gordon Guggisberg, KCMG, DSO, Governor of the Gold Coast and subsequently of British Guiana), was appointed Director of Surveys. He had only recently carried out a survey in the Gold Coast, largely concerned with the river system of the Colony, and of this work, Mrs Guggisberg (formerly Decima Moore of Gilbert & Sullivan opera fame and now Lady Moore-Guggisberg, CBE) wrote an excellent book *We Two in West Africa*.

As Assistant-Director in charge of the Topographical Branch he obtained from the West African Frontier Force the services of Lieutenant (local Captain) R. H. Rowe, Royal Artillery (who after the war became Director of Lands in Lagos), and also from the same source those of Lieutenant Bell, South Lancashire Regiment (now Lieut-Colonel G. H. Keighley-Bell, MC), and of Lieutenant J. Dare of the Loyals. The work of this Branch was at that time principally confined to the forest areas and to arduous traversing with theodolite or compass between a small number of points fixed by astronomical methods.

North of the forest belt, which in the Western Province extends for 50 to 80 miles from the coast, the ground rises to a plateau, from 700 to 1,600 ft above sea-level, of what was then locally called "veldt" or "open bush" country. Fairly level, with few streams, many low scattered trees and some isolated hills or small ranges, it was suited to the pleasanter method of plane-table survey based on points fixed by triangulation. This was, of course, long before air survey had been thought of, for the Straits of Dover had then only just been flown for the first time. It was decided in the first instance to cover with Secondary Triangulation the area lying south of the river Niger, from the Dahomey frontier on the west to roughly the line of the Lagos–Jebba–Kano railway and later to carry on into the Eastern Province.

I was then serving with the 10th (Railway) Company, RE at Longmoor, where reconnaissance survey for, and the detailed survey and actual alignment of, military railways formed part of the training of all officers and of some NCOs of the three Railway Companies stationed there. I was delighted when, out of the blue, I was offered from the War Office the post of Assistant Director, Trignometrical Branch of the Southern Nigeria Survey, at a salary which to a subaltern appeared fabulous and under an officer with whom I had played a good deal of Corps cricket.

After a short refresher course in "star-shooting" at Chatham and a very pleasant dinner in London with "Pa" Close I sailed for Lagos from Liverpool in August 1910. With me came Sergeant Hackett, RE, and two Lance-Corporals, Trim and Gawthorne, from the Ordnance Survey, Southampton; also an Invar Tape Base Measurement Apparatus and a mountain of plywood "chop boxes". These were carefully packed, each to an overall weight of 60 lb for head porterage, with a fortnight's supply for one man of tinned European foods, butter, sugar, cheese, sardines, sausages and so on which I had been warned by the Director were essential to supplement the skinny chickens, minute eggs and scarce fruit or vegetables that would be procurable in my area.

On arrival at Lagos, Major Guggisberg took me into his house for the time which I had to spend in preparation for a nine months' tour up-country. On the first evening at dinner he considerably shook me by blandly asking what I "had done" to get sent out to West Africa—still then rather untruthfully called the White Man's Grave. I hoped that he believed me when I assured him that after 4½ years' service at home I was overjoyed to get abroad and to such a job, and under his command. I also told him in confidence that of what I had been taught at the SME only the fieldworks and survey courses had really interested me—a heresy that would have done me no good with the pundits of AG7; but which was quite up "Gug's" street. In fact my life has run on those lines, for I only did three weeks of "bricks and mortar" in my whole service and for that time, when commanding a Field Company in Egypt, I was DO, CRE and Chief Engineer all rolled into one.

During the fortnight in Lagos we had a try-out of the Invar Apparatus, then a very new gadget. My set had been recalibrated at Teddington after having been used by Major Jack (later Brigadier E. M. Jack, CB, CMG, DSO), on the Uganda Boundary Commission. It rained all the time but one learned the immense advantages of this wire, hanging in a catenary with readings at eye level, over the old-fashioned chain and grovelling on the ground. Survey stores, camp equipment, tools, wire, cement, rope, etc, had all to be drawn and packed into head loads, while introductions to the Governor and officials, a Cricket Match and a Race Meeting helped to counteract the eternal Turkish bath of a climate.

It was good to get away, by train, to Oloke Meji, at the northern edge of the forest, where we were hospitably entertained by the staff of the Forestry Department. Here I found waiting the headmen and carriers for my four parties, and the next day we launched out for our first march of 10 miles to Eruwa where the Director had selected a site for the Base and provided me with an astronomical fixing of its eastern terminal and with notes on a few suitable stations near by.

I set Hackett with the two junior NCOs, the native assistants and their carriers to clear the base line of all trees, undergrowth, rocks, etc to a width of 30 ft. They had also to fix up a ropeway with pulleys so that the measuring tapes could be carried without strain or distortion over a 30-ft wide nullah that intersected our line and to arrange for 5 camp sites along the Base which was to be some 9 miles in length.

During the next seven weeks I reconnoitred my area, travelling 450 miles on foot or pony, selecting and beaconing stations and was able to plan practically the whole of that season's work and get some ideas for the next one. The pony did not last long, for on that short rail journey from Lagos we had passed through a tsetse belt where he had become infected. His hind-quarters soon began to drag and he had to be put down. A bicycle did something towards replacing him, but a cycle was an awkward job for a carrier to push along a rough bush path when "master" was not riding. As the season wore on I began to use a hammock for part of the day's march, which for me was often the preliminary to some hours standing round the theodolite. This hammock was a rhoorkee-type chair slung from a pole carried by two or, on a wide path, four specially selected and uniformed carriers. These men became a sort of aristocracy among that excellent and willing team of carriers who remained with me throughout that tour and of whom many rejoined the next year.

The beacon, or "cockshy", at each station took the form of a tripod or quadripod of stout tree trunks held together by cross bracing and lashed with rope, either imported or the native "tie-tie" made from the parasitic growths which festooned the trees. Thatched down to 6 ft from the ground and provided with a good flagpole it gave shelter to the observer when beneath it and a sound object for him to sight on from afar.

On return to base, a fortnight was filled with planning and then perfecting all ranks in a sound drill for the handling of the Invar tapes and their tripods and in aligning pegs at the correct intervals for those tripods. The measurements, forward and back each took nine days, a normal day's task being two sections each of about 1,000 yds.

Early in the New Year, 1911, I got on the move to start observation of the main triangles and the three NCO parties went out to beacon intermediate points and/or to provide me with helio rays for my observation over long-range shots. Later in that first season I sent Sergeant Hackett for a three weeks' tour to beacon a few main points that I had selected and to choose and beacon such intermediate points as he thought necessary to help the plane-tablers who would follow us. He was late back at our rendezvous and when he arrived he was a very sick man. A few days after parting from me he had started dysentery but, knowing how important for the season's work was the task I had set him, he refused to give in and had completed his whole programme and with excellent judgment as I found when I came to observing in that area. He was literally skin and bone and had to go back

Photo 1. Building a Beacon, or "cockshy" at a MAIN Station.

Photo 2. Base Measurement with Invar Tape near Kano.

Some Memories Of Survey In Nigeria 50 years ago 1,2

Photo 3. The Main Station beacon on the Ado Rock.

Photo 4. The writer and his theodolite at a Minor Station.

Some Memories Of Survey In Nigeria 50 years ago 3 & 4

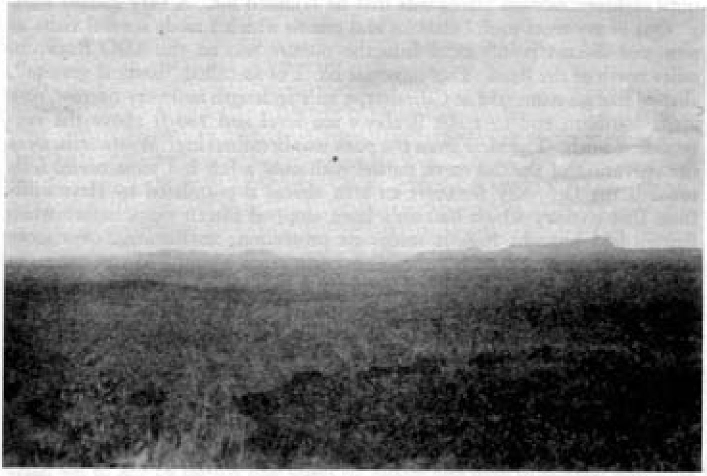


Photo 5. The Ado Rock from near the Dahomey frontier.

Photo 6. Southern Nigeria Survey, 1910–12.
(R to L) *Sitting*. Lieut G. H. Bell, Captain R. H. Rowe, Major F. G. Guggisberg, CMG, Mr E. Cleminson (Dep. Dir.), Lieut G. G. Waterhouse. *Standing*. Two NCOs Topo Branch, Sergt Hackett, L/Cpl Gawthorne, L/Cpl Trim.

Some Memories Of Survey In Nigeria 50 years ago 5 & 6

by hammock to the railway and thence to Lagos and home, and it was not until eighteen months afterwards that he rejoined me. A very gallant man.

One of my most useful stations and one to which I made several visits as new and distant points came into the picture was on the ADO Rock, 20 miles north of the Base. This immense block of so-called "bastard granite", shaped like its namesake at Gibraltar, a mile in length and very narrow, rose at its southern end to 1,500 ft above sea level and 750 ft above the surrounding bush. The view from the peak was breathtaking. Westwards, over the curvature of the flat earth dotted with only a few but most useful hills towards the Dahomay frontier; an area almost depopulated by slave raids from that country which had only been stopped fifteen years before when Britain had brought Nigeria under its protection; northwards, over more undulating country towards the Niger, 150 miles away; and eastwards, in the direction of Ibadan where many of the hills showed forest-clad slopes. If my memory serves me aright it was from ADO that I first sighted a peak of rock away to the south-east that seemed a good peg on which to hang the eventual advance into the Eastern Province. Again and again as I worked eastwards this peak showed up and I learned it was in the Idanre Mountains near Ondo and that there were interesting traditions around it.

Another much-used station was on a hill crowned by huge rounded boulders and inhabited by a large tribe of baboons. These ugly creatures appeared fearless of man and would sit quite still within 20 yds of my party as we moved up the hill. I wondered what would happen did they one day decide that they really wanted the hill to themselves, for one shot-gun and a few machettes would not have provided a very powerful defence.

Twice during this tour I was forced out of my bed by incursions of "driver ants". The rapacity of these pests had recently been exemplified when a couple of railwaymen returning from Christmas dinner at the local NCOs Mess of the West African Field Force were overcome by their hospitality and lay down at the roadside to sleep it off: a column of ants on the move found them and next morning only two skeletons remained. Wakened by bites on my feet I saw lines of ants climbing up the sticks of my mosquito net which was already pressed down close to my face by the mass of the creatures. The only thing they fear is fire and at the second such invasion my boys burnt down my tent in their efforts to dislodge the horde. I sent a piece of charred canvas and some rope to Lagos labelled "one tent for repair" and received by the next up-country train a brand new double-fly tent which I thought to be an example of efficient store management at HQ.

An unpleasant experience came when observing close to the Dahomey frontier in that bare and waterless plain. One evening I went down quite suddenly with a cracking head and fierce pains in the back. Turning over the pages of *Hints to Travellers*—that useful *vade-mecum* of those early days—I found I had the first symptoms of smallpox and, what was worse, that the period of incubation tallied exactly with the time elapsed since I had bought stores in Oyo off a Greek whose face was a mass of running sores. Although I was not normally drinking any alcohol, I carried for emergencies a few quarter bottles of champagne. This appeared to me an emergency and, after downing my "phizz", I went to bed quite mellow. Next morning my head was clear and I crawled up to my theodolite and in forty-eight hours I was quite cured. That Greek, I discovered, had smallpox on him. My theory that the onslaught of this strange form of alcohol had caused the Nigerian bacilli to cry "capevi" is not accepted by my doctor friends, but stranger things than that do happen in therapy.

From my most northerly station at Kishi I spotted above the forest trees the tip of a hill that appeared suitable for an intermediate point in a rather featureless area. As next day I had difficulty in reaching it I asked a native hunter to guide me. He was a very light-skinned man and probably son of one of the copper-coloured, straight-haired "Cow Fulani" women much prized as wives by the darker natives. When we reached the top of the hill he assured me that Kishi was not to be seen from there. However, I had left a helio station at Kishi and when I very soon received an answer to my ray searching across the tree tops at what I knew to be correct compass bearing the hunter fell on his knees exclaiming "the white man is indeed next to God".

It was not until December 1911 that I got near to the Idanre Mountains. As a preliminary I had been forced to spend nearly a week cutting long lanes through immense cotton trees on the top of a 1,900-ft hill at Ilesha to get shots to back stations and forward to my peak. As I moved down to Ondo I thought over the strange tales that I had picked up. How 150 years ago the villagers at the foot of these then uninhabited mountains were much troubled by violent storms that swept down from the heights and damaged their crops. To appease the angry gods they made a sacrifice of a boy and a girl child whom they exposed alive in the hills. History does not relate whether the storms abated, but it does affirm that some generations later parties of fierce hillmen began to raid the same villages carrying off loot and women. By my day peace had descended on the area though hillmen and plainsmen kept themselves much apart. The former were now prosperous and self-supporting, worshipped a God who dwelt in a sacred hill and were ruled by a king who, once enthroned, might never again leave his palace. I had hoped for more information from the District Commissioner, but he was away touring his district and all that I could get from his native clerk was a guide to the principal town in the mountains.

I camped near the foot of the hills and soon after starting off next morning passed the first outlier of the range—a vast phallic monolith, perhaps 1,000 ft high, so smooth that it seemed no baboon could scale it and this struck me as quite likely to be their sacred hill. My path wound upwards through trees and scrub to a steep escarpment which it followed for a mile before reaching the foot of a glacis of smooth rock nearly vertical for 50 ft and about 50 yds in width. This, my guide said, was the only approach to the town and it had to be scaled with the aid of three ropes of "tie-tie" hanging down its face. So up we went, like a Marine commando on the coast of Europe, carefully hauling up the instruments after us.

We found the plateau and the town wrapped in mist and halted in the main square of which the king's palace formed the whole of one side. I sent in my guide and headman with a message of greeting to the monarch and to announce my name and mission in his country. These would certainly be already known through the native "grape-vine" for never had I arrived in any village without finding that everything was known about me and my party and even my own native nick-name, which was always a closely kept secret from its owner and which only the oldest and wiliest of old coasters managed to learn.

A deputation of welcome came out of the palace headed by a magnificent specimen of humanity; tall, strongly built and with a highly intelligent expression. He carried a short stick covered with intricate patterns of closely-set coloured beads as badge of office as Chief Minister to the king. In answer to my request for a guide to the top of the peak that I had seen from afar I was led to a small mound outside the town and assured that this was what I needed—for, said the Minister, the Governor of the Colony had done some survey there years ago and it was, therefore, surely good enough for me. Through the now lifting mist I could see my peak west of the town but they said there was no possible path up that mountain. On asking whether it was their sacred hill, the Minister swung round and, pointing out a very strange looking double-crested mountain a couple of miles to the south, assured me that there lay the sacred hill. With my mind at rest I said that I would find my own way to the top of this neighbouring peak, thanked the Minister for his courtesy, was given leave to park some spare stores in the palace yard, and set off without any protests from my hosts.

We went through the town and found the lower slopes of the hill clothed in forest and a wide well-worn path led us to a big "ju-ju" (sacred) tree with all the customary offerings of bowls of palm wine, bottles of gin, plates of foodstuffs. But to my surprise the path continued onwards; following it up for half a mile or so we emerged on an open smooth rock slope with the peak straight ahead well above and a thousand or more yards away from us.

At the top were some ruined stone walls and much dried grass and a view to every point of the compass; for my aneroid showed the height of 3,300 ft above sea-level and I was right above anything else in sight and well below me was the top of the outlying column seen earlier in the morning.

While a party went back to the forest belt to collect timber for a "cock-shy" I set the grass alight, and as the flames sprung up I heard behind me a sound as if I had disturbed a bee-hive. But the bees were human—far away and down below the population was streaming out of the town with cries and gesticulations. Then I knew that the Minister had lied to me. Doubtless the people were thinking that the angry God had sent down fire to consume the desecrators of his abode, and doubtless they were shocked to see us still alive up there as the smoke cleared away. Feeling that I might as well be hung for a sheep as a lamb I continued my work, built up a fine beacon with a flag atop and took my round of angles.

I am not certain that I picked up the ADO Rock from here, but I have always thought I did so and at a distance of 120 miles over low country, from 3,300 ft one should just be able to sight a peak of 1,500 ft, with a little heat refraction to assist.

Work finished and lunch eaten I began the descent to the town with some trepidation, but when I reached the first house my spirits dropped with a bump. I had known "butterflies in the tummy" before a big rugger match or on the first occasion of drilling the whole battalion at the "Shop" before Public Day, but this was other—it was Fear. The inhabitants were lining my path on either side without moving and without uttering a sound—an unknown phenomenon in Africa—and in the central square they were packed on three sides; not moving, not speaking, just watching.

I took up a central position on my shooting stick and put up my big survey umbrella to keep up my dignity and to keep off the hot sun, but I was very cold inside. As there was no move from the palace I sent my headman and some carriers to collect my stores. But they did not return, so I sent in the guide and he did not return. As a last throw I sent my policeman, a cheery old rascal with brass buttons on his blue jacket and a pair of ragged trousers half way down his shins. After what seemed hours, and was probably ten minutes, out came a procession of all my people with gifts of food piled on top of their loads. I sent in the customary return present to his invisible majesty and started homewards with much relief but no certainty, for there was still that glacis slope to be encountered and I thought it possible that a series of deadly "accidents" might be arranged for us at that obstacle. But all passed off quietly and we reached our camp without incident.

It was six months before I got back to Ondo and the District Commissioner went aboard me for all the trouble that I had caused him. When he had returned to his HQ he had been met by a deputation from Idanre demanding a gift of £50 to pay for the offerings of gin, etc they had made to their God to placate him for the white man's sacrilege. The Commissioner had explained that by regulation he was limited to £5 as a gift; to which they had replied that "from our father, the Commissioner" they would gladly accept for themselves five pounds or five pence but for their God they must have the whole fifty. They were told that the matter would have to be put to the Governor and they decided they would themselves go to Lagos. And there they got their £50.

I asked the Commissioner why, if they were really so angry, they had let me and my party get away unscathed and even without abuse. "To them," he said, "you are now a god and as their own God had not avenged himself, any efforts of theirs to hurt you would have only recoiled on their own heads."

I was never able to cash in on my godhead but had the satisfaction of seeing that my beacon still flaunted its flag on the peak. Nor to my great surprise was I ever mulcted of that £50 by the Government. It is possible that Guggisberg, who always stood up firmly for those under him, protected me though he never spoke of it. I had certainly raised the flag of his Survey Directorate to great heights.

During these two seasons one belt of triangles was run over the "open bush" country from the Base to the Dahomey frontier and northwards to Kishi and thence back south-east to the railway at Illorin, both places about 60 miles from the Niger. The other belt, over more enclosed and partially afforested country, more closely populated and requiring a greater number of intermediate points, went east through Ibadan and Ilesha to beyond Idanre. In my second season I had 2nd Corporal Hosking, RE, to assist in the minor triangulation.

I had hoped in the next season to carry on to the river and to close the gaps between these two belts, but this was not to be for 1912 saw the amalgamation of Northern and Southern Nigeria under Sir Frederick Lugard (later Lord Lugard, GCMG, CB, DSO) as Governor-General. The two Survey Directorates were joined up under Guggisberg and on my return to Lagos in October the whole Trig Branch was ordered northwards by rail. I made a short stop at Zungeru which was then the seat of the Northern Government. The next morning on the way to the Government offices I saw in the road a woman's corpse and running about under the surrounding tree numbers of the WAFF with rifles at the ready. At the gate of the Secretariat stood Lieut-Colonel Strickland (later General Sir Peter Strickland, KCB, KBE, DSO) and his adjutant, with sporting rifles. The colonel told me that one of his men had run amok, murdered his recently divorced wife, fired into some of the bungalows and gone spare, and he was hoping that the bird would break his way. Indoors a very white-faced young secretary asked whether I knew that the WAFF had mutinied!

After a short visit to Kano to select a base and arrange for its preparation, I returned by rail to Zaria where I picked up Sergeant Hackett, back again at last from the UK, and we went by rail and on foot to Naraguta on the Bauchi plateau. Here at the HQ of the tin mining area I measured a base and started providing a series of points to assist the Cadastral Survey in delimitating the areas allocated to the various Companies. This job I soon handed over to Lieutenant H. E. Kentish, RE, just out from home to join the Branch and I took myself and the Invar Apparatus to Kano where I followed a similar procedure with a base between the town (still in those days surrounded by an unbroken 11-mile circuit of walls), and the British cantonment.

On New Year's Day, 1913, Sir Frederick Lugard held a Durbar attended by all the northern Emirs and Sultans; Kano, Sokoto, Katsena, Zaria, Bornu and others. There were some 50,000 men on the ground, of whom 15,000 were mounted. British power was represented by a few companies of Mounted Infantry, one of Infantry and a Pack Battery of the WAFF, all without a round of live ammunition. A good instance of the "oppressive" nature of our colonial rule of which we nowadays hear so much from ignorant and evil mouths at home and abroad.

As each Ruler and his people passed the saluting base—the grand stand on the Racecourse—a party of horsemen would wheel inwards, gallop up to the Governor-General, rein up and salute him with firing of rifles and matchlocks and with wild cries. The most impressive of these were the warriors from Bornu wearing chain mail of which some is supposed to be real Crusader loot. But it was the Emir of Kano who "stole the show", riding past on an immense white camel with a red and gold umbrella held above his head.

This was the end of my tour for I had been given a coveted appointment as Instructor of Military Engineering at the Shop and was to be replaced, as Assistant Director, by Lieutenant Bulkeley, RE, who had just completed his tenure of that job. That well-known Army and Devonport Albion forward was the wearer of a monocle which at a later date is said to have saved his life when he was carrying out triangulation in the Munchi country of the Eastern Province. Surrounded by an extremely angry and hostile crowd of armed tribesmen he screwed the glass into his eye, the sun caught it and the flash so frightened the natives that they fled incontinently enabling his party to get safely away.

I travelled home on the first available ship which happened to be German, and among whose passengers were a number of officers from the Cameroons. It was pleasant to hear that before going out they had to learn English as the troops in that country refused to be drilled in any other tongue than what they called "the talk of soldiers". I arrived back a week late for the Shop term and immediately suffered the indignity of going down with *German* measles, coupled with malaria, of which I had not had one touch during the whole of my tour abroad. As in addition I had brought home an intestinal parasite that reduced me to the last stage of anaemia before the doctors rid me of it, I was not of much value nor did I much enjoy life until well into the summer.

It had been a grand experience; of responsibility in planning and carrying out a job, of control of men, and of endurance of fatigue and climate. And, not least, I had seen how the country was run by a handful of devoted men, civil and military, bringing peace, good order and prosperity to a vast territory.

Eighteen Coral Atolls

By LIEUT-COLONEL D. G. RASCHEN, RE

PREPARATIONS

IN May 1960, just before I left England for Christmas Island, I was told that the Gilbert and Ellice Islands Colony had asked the Corps for advice on the clearance of coral. The scope of the task was doubtful and so were the means of undertaking it. The only thing which was certain was that if a reconnaissance could be arranged it would be carried out by the OC 73 (Christmas Island) Squadron: this would be my job. I was advised to read "A Pattern of Islands" by Sir Arthur Grimble, who spent many years in the Colony, and I much enjoyed doing so. From this and other sources I started to find out about this very remote part of the world.

The Colony lies in the Central Pacific and is divided both by the equator and the International Date Line. Excepting Ocean Island, which produces the highest grade natural phosphate in the world, all the islands are coral atolls. There are about thirty-five in all, sixteen in the Gilbert Islands, nine in the Ellice, seven in the Phoenix Group of which four are normally uninhabited and three in the Line Islands, including Christmas Island. The Colony is so widespread, only 360 square miles of land in 2 million square miles of sea, that the recent Resident Commissioner, His Honour Mr M. L. Bernacchi, CMG, OBE, was the first officer administering the Government to have visited all inhabited Islands. The map at page 300 shows the area.

Financially the Colony is just self supporting. Half the revenue comes from the Ocean Island phosphate and half from a tax on copra exports. Copra is the partially dried meat of the coconut and, like other edible oils, is in great demand, particularly for the margarine industry. To be exported the copra must be shipped off the islands and this presents the problem.

Most of the atolls are surrounded by a flat fringing reef some hundreds of yards wide which is dry at low tide and covered by a few feet of water at high tide. The reef edge drops away so steeply that there is often no anchorage for ships. To collect the copra the Colony vessels each carry one or two surf boats which are rather like small lifeboats, about twenty feet long and ten feet wide, carrying 4 tons of cargo when fully laden. The surf boats can only reach the shore around high tides, and from October to March, when westerly winds may blow, even canoes cannot cross the reef edge safely.

Much shipping time is wasted and some of the incentive for producing copra is lost.

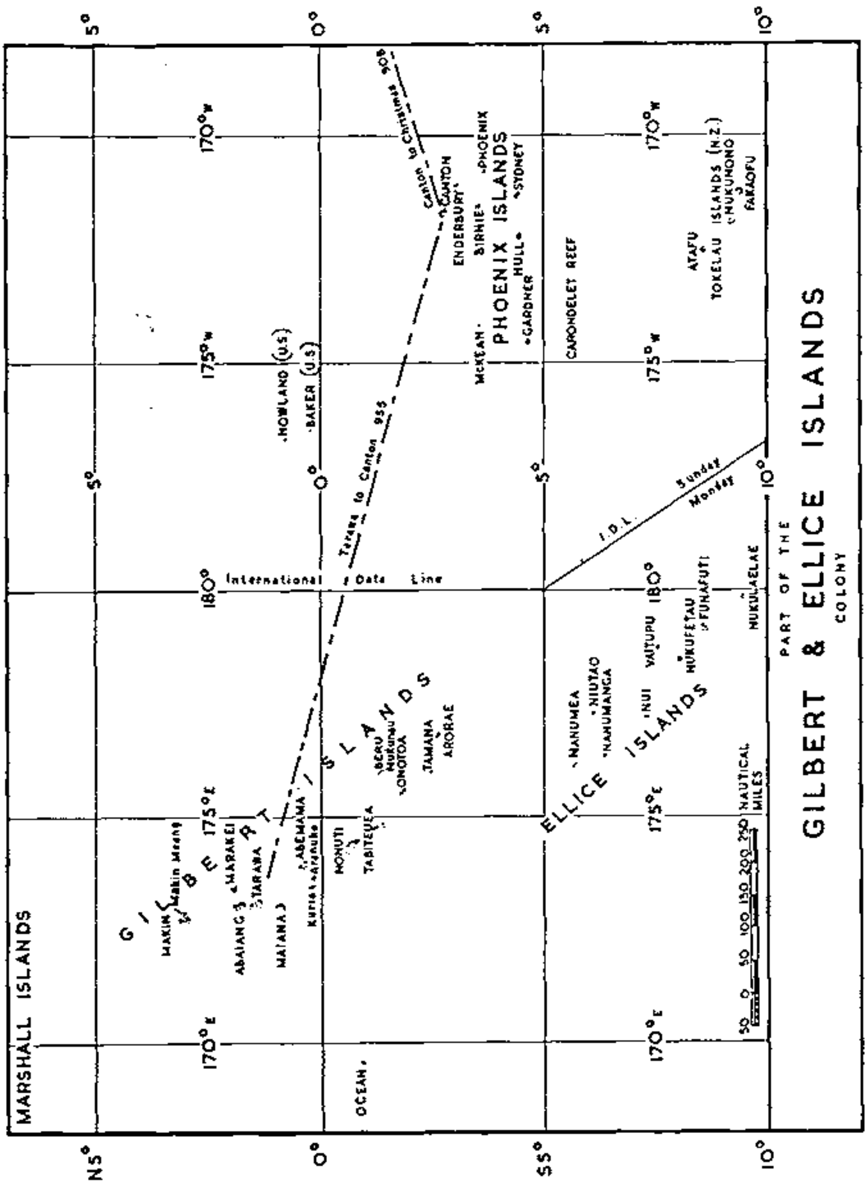
In 1958 the Colony were offered a grant from the Colonial Development and Welfare Fund for allocation to a suitable project. It was decided that this could be spent to best advantage in improving the sea access to as many of the islands as possible: no less than twenty-five had requested help. The useful, but not excessive, sum of about £60,000 was earmarked for the project.

I was given the impression in London that the work would mainly consist of clearing coral heads, pinnacles of coral rising to the surface from 10 or 20 ft below, from existing channels. This proved to be a misconception, but resulted in two naval divers from Christmas Island being booked for the reconnaissance. At that time I knew nothing about coral (I thought it was pink and suitable for necklaces), nor of the formation of a coral atoll, and still less about how coral could be demolished. About its demolition I could obtain no information in England, which was disconcerting, and had to hope that the Americans in the Pacific could give me some background knowledge.

About the formation of coral I did run some information to ground and for those who are as ignorant as I was, here it is. Coral polyps are minute underwater animals which extract lime from sea water and deposit it on their living tissues. In this way the hard white coral rock is made. Coral grows in many different forms, from great coral heads up to 20 ft in diameter to delicate plant-like forms known as "branch" or "staghorn". Several conditions determine whether and how fast coral will grow. Reef corals do not flourish at temperatures of under 75°F, consequently most reefs are in tropical waters. Coral will not tolerate fresh water and so would not grow opposite the mouth of a stream; in fact coral atolls are so porous that there are no streams, but this effect is seen on mountainous islands fringed with coral. Coral must have sunlight and consequently will not grow below about 100 ft depth of water, nor will it survive for more than a few hours in air (the smell is sweet and sickly), so upward growth is limited to the level of mean low water. Lastly the sea water must be moving to bring the food to the coral; sediment cuts off both the food supply and sunlight and kills it. The form a coral takes and the rate it grows depends on the interplay of these factors and explains why each builds into a unique and individual structure. Rates of growth of inches a year by hard coral heads and feet a year by soft branch corals are probably achieved in good conditions.

I left England on 5 June arriving at Honolulu the next day, where my predecessor from Christmas Island started to hand over to me. Within a couple of hours we had discovered a helpful US Navy officer at Pearl Harbour who kindly rang round several units asking if they knew anything about coral blasting. It was soon obvious that very little had been done since the war and little was remembered of what had been done then. However, he eventually contacted a US Navy Explosive Ordnance Disposal Unit and received a strong affirmative to his question. We asked an officer to lunch and conducted useful business. That evening he and his friends entertained us royally and we made arrangements for them to visit Christmas Island to teach the trade.

Two officers duly arrived about three weeks later. They were both divers and their experience of coral blasting was chiefly based on deepening


GILBERT & ELLICE ISLANDS
PART OF THE
COLONY
MARSHALL ISLANDS
PHOENIX ISLANDS
ELLICE ISLANDS
International Date Line
Tarawa to Canton 955
Canton to Christmas 908
I.D.L.
Sunday
Monday
HOWLAND (U.S)
BAKER (U.S)
CANTON
ENDERBURY
BIRNIE
PHOENIX
SYDNEY
HULL
GARDNER
McKEAN
CARONDELET REEF
ATAFU
TOKELAU ISLANDS (N.Z.)
NUKUNONO
FAKAOFU
MAKIN
ABAIANG
MARAKEI
TARAWA
MAIANA
ABEMAMA
KURIA
NONUTI
TABITEUEA
BERU
ONOTOA
TAMANA
ARORAE
OCEAN
NANUMEA
NIUTAO
NANUMANGA
NUI
VAITUPU
NUKUFETAU
FUNAFUTI
NUKULAELAE
NAUTICAL MILES
50 0 50 100 150 200 250
170°E
175°E
180°
175°W
170°W
N5°
0°
5°
10°

existing channels over coral for big ships, working at depths of 20 or 30 ft. I still had no clear idea of the requirement in the Colony (telegram was the only means of correspondence), but spent three days taking them to see various coral obstacles on the island and asking them what their method of attack would be. I gained three impressions: that coral was an unsatisfactory substance to blast; that surface charges were often the only answer and usually terribly uneconomical, and that boreholes presented many difficulties. We asked about the use of shaped charges under water, but their efforts to make the stand-off distance watertight had resulted in buoyant charges, a problem which I knew others had encountered. Although the task in the Colony later proved different to any we had discussed with these two officers, the background knowledge they gave us was of great value. However, during our reconnaissance my ideas regarding the best methods of explosive attack were changed many times.

Our reconnaissance party was to consist of four, my Squadron Sergeant Major, WO 2 J. T. Cheeseman, who had wide experience of demolitions, and myself as the sappers, and Lieut-Commander B. J. W. Mitford, RN, and a rating as the two divers. As with most schemes in the Central Pacific, travel arrangements produced the greatest planning problems. It had initially been thought that the trip could be completed in sixteen days: in fact, rushing things, we were away six weeks. The only possible means of transport were Colony vessel or RAF Hastings aircraft, but a great deal of conflicting information on availability and feasibility confused the choice. The only course which I had been told was definitely impossible, suddenly at a late stage became possible and was the one we took. The planning involved many cornered contact between all three Service Ministries, the Colonial Office and the Colony, as well as the Ministry of Aviation, our parent Ministry in Christmas Island, who, not surprisingly, were determined that someone other than themselves should pay for us and everything concerned with the trip. It would obviously not be cheap, with Hastings at six shillings and sixpence a mile and Colony vessels at just under a hundred pounds a day.

At short notice we were told that a vessel with H.H. The Resident Commissioner and Mrs Bernacchi on board could take us. No final approval for the financial aspects of the trip had been received, so I signalled that unless I heard otherwise I proposed to proceed. It worked, and the sense of achievement in even starting the trip was great. The charts which we had requested from the Admiralty Hydrographer at Bath arrived the day before we left.

The Journey

Our ship for the first part of the journey was the MV *Maona Raoi*, 150 ft long and 504 tons. We left Christmas Island for Canton in the Phoenix Islands on 17 July 1960. This leg of the journey I particularly remember from two points of view. Firstly, the Pacific Ocean did not live up to its name and sea-sickness overcame me: to add insult I discovered that "Moana Raoi" means, loosely, "calm sea". Secondly we had the experience of severe illness at sea with no doctor on board. Lieut-Commander Mitford was the patient and we treated him for peritonitis which was the best, and rather depressing, diagnosis the ship's Master could make from his medical book. Most fortunately we were only 20 hrs from Canton where an emergency operation was completely successful.

We left Mitford on Canton, to be flown later to Honolulu, and with him his rating as, for safety reasons, a diver is not normally allowed to work alone. That left just SSM Cheeseman and myself. In fact the departure of our divers did not prove such a severe blow on the reconnaissance as we expected.

The next day we sailed from Canton, a very barren atoll on which one of the "Man in Space" tracking stations was being built, and arrived at Hull island in the Phoenix Group the following morning. It is an atoll about 5 miles long and 3 miles wide, consisting of a narrow strip of land enclosing a 10-square mile lagoon which has no access for boats from the sea. This was the first island on which we were asked to advise, as the only method of working from ship to shore was over the reef. We anchored in the only, and what is described as "precarious" position, about 150 yds off shore from the village. The water was wonderfully clear and we could see the bottom on which we were anchored, 12 fathoms down.

The SSM and I went ashore in a surf boat at high tide and soon discovered that bathing trunks were the best dress for our work. The reef was a flat coral slab, probably many corals knit together by algae action over the ages, only about 60 yds wide. We were asked to suggest how a 20-ft wide channel, 3 ft deep, could be cut to the shore from an existing fissure, or chute, at the reef edge. With a tide range of only 4 ft this would give access for copra boats at most tides. We found our most useful tool a crowbar, with which we tried to break off samples of the extraordinarily hard, concrete-like, coral. We were the idols of dozens of small children, who considered our occupation, at the least, curious.

Certainly the conventional and best way to do this job appeared to be boreholes, but circumstances made the conventional appear difficult. Firstly, the Colony had no compressor and, even if one were purchased, to put it ashore from one of the tiny vessels available would have been a major task. Secondly, surf would probably prevent the drilling of boreholes on the reef edge. Thirdly, the rubble must somehow be cleared from any channel blasted: like compressors, it would be still less possible to import an excavator. And fourthly, the village was at the very end of the proposed channel; fortunately there was very little glass which could be broken by blasting. In the absence of anything more practical my initial proposal was for surface charges laid at low tide and fired at high. This would require more than 2 tons of explosive fired in many small charges to avoid blast damage.

It had been agreed that the aim of our reconnaissance was "to assess the feasibility of economically improving sea access to islands in the Colony, with a view to recommending suitable methods of carrying out the task". Although we, as Sappers, were carrying it out there was no guarantee that the Corps would be offered any tasks which we recommended. There had been thoughts of perhaps a civilian with demolition experience taking it on. However it seemed best to plan as if it were a Corps task. First indications were for a few men for rather a long time.

The Phoenix Islands are off the beaten track of Colony, or any other, vessels and I think we were the first ship at Hull for a year. After certain arguments about loading copra on a Sunday we sailed again at midday for Gardner. The Colony only came under the British flag in 1892, since when the entire population has become Christian. About one half are Roman Catholics and the others adhere to the London Missionary Society.

Gardner proved to be a charming little island, just under 4 miles long and shaped rather like a horse's head. The blasting problem would be much the same as at Hull, but the reef was wider, so yet more explosive would be required. The sun was out as we crossed the reef at high tide and it was lovely and rather awe inspiring to see the edge coming up out of the depths like a mountain face. We bumped it as we crossed and the Gilbertese oarsman who was standing on the stern of our surf boat fell into the water. On the way in, between the ship, which could not anchor, and the reef, we had been greeted by a couple of large sharks. The speed with which the oarsman regained the boat was remarkable.

Fortunately before starting on the journey I had devised a number of questions to which I wrote down the answers at every island. My guide at Gardner was the "Chief of Kaubure", or Headman. Doubtless he was one of the worthiest souls, but not the easiest to question through an interpreter. I phrased my questions carefully; for instance, "Where would you like a channel built?" "Do you understand what explosive is?" "What are the highest and lowest tides here?" "Does anyone ever get hurt by sharks or fish?" "How do you get drinking water?" and, "Are there any windows with glass in them?" The interpreter, who was the local wireless operator, certainly did his best and within a few minutes of asking each question managed to obtain either a "Yes" or "No". I did not hurry to the next question as I could see that the C of K was worried. Sure enough, a little later the interpreter would say that he was sorry, but what the C of K really meant was "No" or "Yes", as the case might be. I would not put too high a rating on the intelligence I gained!

The paid Government staff on each of the islands includes a Magistrate, the Chief of Kaubure, the Scribe, the Wireless Operator (the wireless system is good), the Dresser at the Dispensary and generally a school teacher, also a few policemen, all of them being Gilbertese or Ellice. The Europeans are concentrated on the larger islands and Administrative Officers check the work of the local government by periodic visits.

Buka trees grow on Gardner. These are tall and deciduous and are hollowed to make canoes. On most of the islands there are only coconuts and some pandanus palms. Every possible bit of ground carries a coconut tree, a necessary situation with a rising population in the Colony, already 50,000, and fish the only other common food. If all the coconuts are eaten there is no copra to export.

Most of the islands have a Rest House and the one on Gardner is particularly fine, built out of pandanus wood and thatch and overlooking a beautiful lagoon. The Rest Houses could provide accommodation for small work parties.

Our trip to Tarawa was uneventful and with the wind and swell behind us we made 9 knots, a great speed. We omitted the day 27 July on crossing the Date Line westwards and arrived at Tarawa, the capital of the Colony, on the 30th. It is a large atoll, consisting of a series of narrow interconnected islands on the south and east sides of a fine lagoon, which is navigable through a gap in the barrier reef along its north-west side. Tarawa's chief claim to fame is that the US Marines achieved one of their first major victories over the Japanese there on the return across the Pacific. I was conducted on a most interesting battlefield tour.

We were kindly asked to stay in the beautiful Residency over the August Bank holiday as no shipping would be available for a few days. Our arrival was reported in the Colony news sheet and it was a little embarrassing to be greeted by interested locals with: "Oh yes, you are the experts on blasting coral", when, mainly due to lack of accessories on Christmas Island, neither of us had ever blown up a sizeable piece of coral.

Just before we embarked on the MV *Ninikoria* to start our reconnaissance in earnest we discovered that our precious crowbar, one of the few items we found useful in the rather cumbersome recce kit which we had in ignorance taken with us, was missing. It had certainly been taken off the *Moana Raoi* and we could only conclude that the policeman who delivered our kit must evidently not have considered a crowbar a suitable piece of personal luggage to take to the Residency. We managed to borrow another and in doing so were shown round the Public Works Department resources, which were small. Stores brought into the Colony are shipped from Australia on a phosphate ship to Ocean Island, and then transhipped to Tarawa.

We had discussed plans with Captain Douglas, the Marine Superintendent for making the best use of the time and shipping available to visit as many as possible of the islands where work was required. We agreed that the minimum time at any island should be at least one low tide. He accompanied us on the remainder of our reconnaissance and it was an enormous help to know exactly what the requirement was and what concessions, if any, could be made.

We arrived at Marakei, about 40 miles from Tarawa, late on 2 August. It is a pear-shaped atoll with an almost landlocked lagoon. The official Admiralty chart is a sketch by Captain Wilkes of "a US expedition" of 1841 which carries the note that "Marakei Island is reported to lie about five miles westward of the position shown". It was reassuring that *Ninikoria* had radar and that we approached in daylight. Captain Douglas made some corrections to Captain Wilkes' sketch whilst we were there.

The SSM and I stayed ashore, or rather in the water, until dark. The normal landing place is a village called Rawannawi and improvements had been requested there. Complications were that the approach was not solid coral, but mud and coral rubble which would silt again even if blasted, and that the Roman Catholic church and priest's house were only 50 yds from the end of the required channel. The priest was a Belgian and I had some difficulty explaining to him why I had come, and even more in tactfully asking how much he valued the church windows, which looked vulnerable. As we continued on our journey we were to find churches a recurrent problem. We were usually asked to provide a channel on the sheltered side of the island, opposite the main village. In the village, often right on the shore, would be, by local standards, a remarkably fine church, contrasting strangely with all the other thatch hut dwellings. Even the London Missionary Society churches were ornate and stained glass greatly enhanced the value which the islanders placed on their beauty. To my prejudiced eyes the glass was a great nuisance.

Our methods of surveying a proposed channel were very simple. At the shore end the SSM would stand, holding the end of a strong line knotted at every 10 yds. We noted the tide level and then I started backing out to sea, carrying a 6-ft rod. At every knot in the line I would shout out the depth of water and the SSM would book it. When I got nearly out of my depth, or to the reef edge, I knew that I had gone far enough. We had proper levelling equipment with us, but in the surf it would be rather impractical. I considered that using the water as my level and the feel of the current around me it was possible to judge levels within 3 in, which should be good enough. Our foolproof method failed, however, when we tried to pinpoint some classic-shaped coral heads at the entrance to the channel. We tied our line to a datum point on the shore and backed our boat out towards the surf. Just as we were making the measurements we wanted, the line parted. I was sure that the hordes of interested children had cut it, but fortunately repressed my wrath, as the line proved to be rotten. Controlling the children would be a real problem if one were blasting. We were rather frightened of some jelly fish in the water as we waded, but were later reassured to find the children eating them raw.

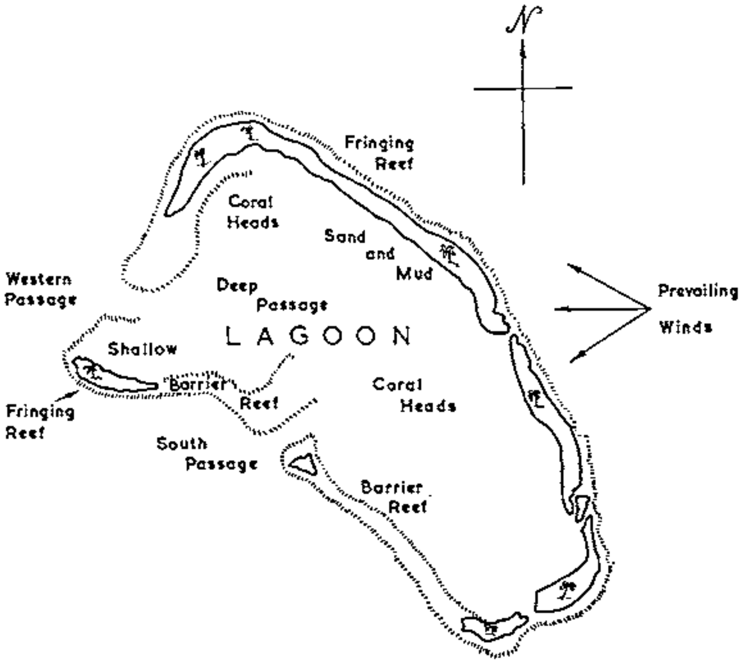
We spent the next morning on Marakei looking for other more suitable landing places. It is an island of legends, the strongest of which is that on landing for the first time one must go round its perimeter anti-clockwise, otherwise one will surely die. We were told it was a 5-mile journey and were lent brakeless bicycles. The path was none too good and in fact we went 17 miles, but it was a very pleasant island, well worth seeing. We found a possible site for a landing about 2 miles from Rawannawi. The bottom shelved from the shore to 6 ft deep in 40 yds in the form of a series of interconnected pools between pillars of coral. Normally I have to wear spectacles and I found that my gas mask spectacles were most effective under a face mask. The hundreds and thousands of little beautifully striped fish, watched by one much larger bluey-green parrot fish, were a lovely sight.

We later checked the entrance to our newly proposed channel with the ship's launch fitted with an echo sounder. It proved unsuitable as an anchorage, as just beyond where I had been swimming the reef shelved away at about 45 deg into the depths. One mile off shore the depth is 2,000 fathoms, so we are told.

We called at Abemama, a lagoon island where R. L. Stevenson once lived, the next day. The requirement was to clear the silted channel beside the loading mole which runs out into the lagoon, but I was unable to make any constructive suggestions within the finances of our scheme.

Abemama's shape shows well how an atoll is formed. Mountain ranges in the Pacific are known to have risen and sunk through the ages and, if my theory is correct, most atolls are based on mountain or volcano tops which have sunk through the sea's surface at a rate sufficiently slow for coral to form. Other atolls may have grown up from mountains which originally nearly broke the surface, but, considering the great depth of the sea and that coral only grows fairly close to the surface, the occurrence of many mountains of a height almost exactly equal to the depth of water would seem statistically improbable. As the coral grows it is broken off and piles up as a strip of rubble inside the living reef, gradually filling in any volcano crater. On the weather side the waves throw rubble above tide level and vegetation takes root; the process on the lee side is slower, but a barrier reef is thrown up by the occasional westerly storm. A lagoon is left inside the rubble ring of the atoll, due to the light silt washed over the rubble reefs having stifled the living coral. The coral reefs and coral heads found in lagoons are usually secondary growths founded on a sand base.

We had been asked to give the next island, Maiana, special attention. It is a relatively big island producing quantities of copra and palm thatch, but with most unsatisfactory means available for shipping them away.



ABEMAMA

Scale approx 1 nautical mile to half inch

We were asked to suggest a means of clearing a ship passage at least 10 ft deep for Colony vessels through the barrier reef and into the lagoon, to give an anchorage as near as possible to the Government Station on the far side. We spent a wet, rather miserable and remarkably cold two days trying to find one, or an alternative boat passage, and failed. Frequently we thought we had the answer, but each time the passage through the reef dwindled to a few inches of water. Air photos might have helped our search, but with the nearest military airfield thousands of miles away there was little hope. The only positive things we established were that the alignment of the barrier reef was dangerously wrong on the charts and that a possible boat passage quoted in the navigation manuals was entirely ficticious.

Ninikoria was required for other duties and we returned to Tarawa rather depressed. Each task we had seen had its own particular snags and I lacked confidence in my only positive proposals, for the use of large quantities of explosives as surface charges, especially as I had no practical experience of the method.

We were on Tarawa for two days and again were entertained royally. We also spent an interesting morning seeing the new harbour which was being built by Gilbertese under the supervision of a single British engineer. He gave us ideas on organizing labour in the Colony and spoke most highly of the Gilbertese as workers and tradesmen, providing they were supervised. The problem was to find suitable supervisors from amongst them. Whilst seeing the harbour I noticed the vast number of ex-American gas cylinders used as bells for every purpose such as fire, school, knocking off work and church. I asked a local how he would know if the fire bell were being rung and was told: "That is simple, it is painted red".

The last sea leg of our journey was made in the MV *Nareau*, wooden, 84 ft long, just over 100 tons and the joke of the Colony. We had two weeks to see as much of the Southern Gilbert and Northern Ellice Islands as possible. The problem was to know when to come back as the engines were very tired and for most of the way only made 5 knots, on which the 2-knot east to west set in the area had a significant effect.

On the way to the Ellice Islands we called at Aranuka, which set quite a new problem, and was the only time we really missed the advice of divers. Boats could, under favourable circumstances, just pass through the barrier reef to the lagoon and thus to the Government Station 2 miles away. There was no real channel, just a zig-zag and treacherous route through the coral heads. The lagoon water surged out with a falling tide at, I estimated, 6 knots and we spent a most unpleasant five minutes in our little launch unable to make any headway against it. Conditions for coral growth must be about perfect and we were asked to suggest how some of the massive coral heads could be removed to reduce the hazard to copra boats on tow. The heads appeared as great orange, yellow or rusty red pillars, 10 or more ft in diameter and breaking the water's surface from about 20 ft below. Some seventy needed attention and we thought each would need about 200 lb of explosive. I hoped that divers would be able to fix charges at slack water, but it would be a tricky problem, especially with wounds from coral abrasions being so difficult to heal.

We were taken ashore to Nanumanga, our first Ellice Island, in dug-out canoes. These are hollowed from buka wood and the shell is so thin that on no account must weight be put on it. There are 2-in square cross members every few feet along the gunwale; balancing onto these, in wet rubber-soled shoes with the canoe pitching several feet against the ship's side, was quite exciting. It was all a case of letting go of the rope from which one hung at the right time and then accomplishing the second stage, of sitting down, also at the right time. I soon discovered that the canoe's outrigger, which gives stability on the move, gave none at rest. Reef edge crossing in a canoe is a great art and it was of particular concern to me that day. At one moment there were 4 or 5 ft of water over the edge and at the next great foaming coral heads, covered with a form of red litchen, bare and right in our path. This was part of the hazard we were asked to eliminate. My two paddlers managed, it seemed by magic, to wait until the right wave and then paddle furiously over the edge. They inspired great confidence, which was as well, as the view over the canoe's side appalled me.

We were greeted by the island Headman and the usual mass of inquisitive children who stood at our elbows and were thoroughly embarrassing as we tried to ask questions through the interpreter. My explanation that we were not going to blow a passage through the reef that very day gained their vocal disapproval. My questions about the highly breakable stained glass windows in the church were greeted with every form of suggestion, of which some I did not think their pastor would approve. There would be nothing very difficult about making the channel they want, if it were not for the church.

At our next island, Nui, we found an existing, but incomplete, boat channel, built by a resourceful District Officer called Kennedy, before the war with local labour. There had been no doubt in my mind that to move coral economically, as with rock, the explosive must be used to lift it. However, I had shied away from boreholes as I could see no way of transporting or landing a compressor to bore them, and also there were stories of coral gripping the bits. Mr Kennedy was not worried about the possibilities of a compressor, so gave the locals crowbars and sledge hammers and told them to proceed with boreholes, and it worked. We found some of these holes, which can never have been filled, about 2-in in diameter and 18-in deep. Our minds turned to "bars jumping and boring" of which both the SSM and I knew little.

Nareau had been to Ocean Island just before we came on board and had obtained for us some blasting explosive. We tried a 10-lb surface charge tamped with a couple of sandbags on the reef at Nui. It drew the spectators, but the result was most disappointing, just a small pocket on top of the coral. The explosive oozed nitroglycerine and I blamed it, especially as it gave me a bad headache. When we went to ground in the remainder of the 50-lb box we found a large puddle, so threw the contents overboard, very gingerly. In fact we proved the disquieting result of this blast to be only too typical as soon as we were back on Christmas Island. Even firing in two stages, first blowing a pocket in the surface and then filling this with explosive, it is difficult to blow to more than 1 ft depth through coral with surface charges.

Hand-made boreholes changed my whole outlook on the scheme. The one thing that is available in the Colony is strong, and if it is for their own good, willing labour.

We later managed to contact Mr Kennedy in retirement in the Solomon Islands and he wrote a most interesting account of his methods. He had none of the advantages of detonating fuze and there was a nice description of a series of men lighting safety fuzes at the same time with cigarettes. I had been advised by the Americans to use safety fuze initiation for any charges in sea water, always having the detonator on a float on the surface, or on the shore. Our later trials proved this to be good advice.

At Nanumea, our next island, I still had such a headache that I asked the SSM to go ashore alone with Captain Douglas. They were greeted by four canoes of smart Rover scouts at the ship and, having been duly appreciative of their reception, proceeded ashore in their normal reef wading clothes, which in the SSM's case was a pair of bathing trunks, shoes and an old shirt. To his horror he was greeted on arrival on land by yet more Rover Scouts drawn up as a Guard of Honour which he was expected to inspect. As a graduate of a Guard's Drill Course he said he had never wished more to be swallowed up by the reef. Worse, they were then asked to give the Gilbertese a talk on world affairs. It was the only day I did not go ashore, and I am not sure if he believes the excuse I gave. The blasting task would have been about the same as at Nui, a 15-ft wide channel 3 ft deep running for about 200 yds across the reef and into a funnel over the reef edge. On 16 August we returned to the Southern Gilbert Islands, to Arorae, a charming and highly efficient island. Like many of the smaller atolls it is just a narrow strip of land with no lagoon, surrounded by the reef. We spent a most enjoyable day and I could not fault the place. Even the children were disciplined and the channel that was required was nowhere near a church. Tamana, where we landed the next morning at 5.30 am to catch the tide appeared a very similar place, but the channel and church clashed and at that hour in the morning I could not give them the benefit of the doubt. The same evening we arrived at Onotoa, and tried without success to find a ship channel into the lagoon.

It was most interesting visiting so many islands, but it took me two hours to write up my report on each and I dreaded doing this with *Nareau* rolling, as she did even in a still sea.

The next day at Beru, one of the larger islands, we had two completely different places to look at, one at the bottom and one at the top. We went ashore early at the south end, and I had no difficulty in understanding the requirement as our canoe bashed the reef edge in quite a light surf. Both my Gilbertese paddlers departed into the water whilst I sat tight trying to look dignified and making efforts to assist, such as retrieving a floating paddle and a lava-lava, a kilt-like piece of apparel worn by the Gilbertese. Anyway we found a place which we considered suitable for a channel and with no churches within 2 miles, which was an unexpected mercy as Beru is the Colony Headquarters of the London Missionary Society.

Nareau moved up to the north-west corner later in the morning to a really attractive little anchorage, almost a harbour. Again we were shown a place where improvements looked fairly easy and it was pleasant to write an encouraging report. The channel contained some lovely growing corals, greens, yellows and purples, but unfortunately it quickly loses its colour when removed from the water.

On our way back to Tarawa we visited two more islands. Tabiteuea, which is the largest island in the Colony, excluding Christmas Island, presented us with rather the same problem as Maiana. We could see the great need for giving access to the island, but again we could suggest no economical solution. We spent the day taking soundings from the launch. Whenever we did this it seemed to rain or blow, and this was no exception. We did go ashore, wading for about half a mile over mud, but in the time available had to admit ourselves beaten.

Kuria, the last island was a pleasant place, comprising two small reef islands with a shallow gap of about 100 yds between them. The inhabitant's professed difficulties in loading copra appeared to us to be due to them having the copra store on the wrong half of the island. Kuria had a lovely sandspit sheltering a natural bathing pool, one of the few islands we saw where it would have been safe to bathe in the sea, as in most places the surf on the reef edge was too ferocious.

We arrived back on Tarawa on 21 August and a fortnight in *Nareau* had satisfied our immediate desire for travel. My descriptions of our journey have, of necessity, been brief. Unfortunately it has been many of the things which made the trip so interesting, the scenery, the sunsets, the legends, fishing over the ship's stern and stories of the charming inhabitants of the islands, which have had to be omitted. It was certainly a memorable journey from every point of view and we were extremely fortunate to have the opportunity of making it.

Proposals

We spent six more days on Tarawa before leaving. These were spent in obtaining outstanding material for my report and briefing the Resident Commissioner. Again the kindness and hospitality of the European residents was overwhelming. A Hastings aircraft arrived from Christmas Island, via Canton, bringing a large number of sightseers including our padré, who promptly found himself booked for a christening the next day. The pilot said he never wished to land a Hastings on an airfield narrower than Bonriki, the Tarawa strip; the space between the wing tips and palm trees was frighteningly small and this was the first plane to land for over a year. We left on 27 August, and after nine hours flying via Canton arrived back that evening at Christmas Island the day before we left, having crossed the equator from north to south and south to north and the International Date Line during the day.

We had visited eighteen atolls and been given every opportunity to see the requirements. The time had now come for my bluff to be called as I was bound to commit myself to paper. The two main questions were: "Was the task worth tackling?" and "How much could be done for the money?"

I was sure that on the reef islands the task was worth tackling. Within the financial limitations of the scheme I could not suggest anything practical for the lagoon islands, such as Maiana and Tabiteuea. This was a great pity, as from the commercial point of view their need was undoubtedly the greatest. However, improvements at the reef islands would result in saving of shipping time which could be used at the lagoon islands, so all should benefit.

So far as blasting methods went my thoughts were clearer, though many practical trials were required to confirm them. Where any depth of blast were required, 1 ft or more, hand-driven boreholes would have to be attempted. Self-contained power drills appeared a possibility, but at the time I knew of none which were adequately reliable mechanically or which I thought would continue to work when frequently swamped with surf. Where boreholes could not be used, such as on the reef edge or coral heads, large surface charges placed by shallow water divers would have to be used, firing at high tide to obtain all possible blast cushioning from the water. The explosive requirement looked like being about 30 tons and a major problem would be that of transporting it to the Colony under peacetime safety precautions.

"How much could be done for the money?" was an all embracing question. I considered that, unaided, the Colony could not take on a comprehensive scheme with its own resources. It was, therefore, a case of what manpower and what resources would be required from outside. I had been told that any Sapper party would have to come from the United Kingdom. Bearing in mind that a return fare from England to Tarawa is about £700 and that all pay and allowances would be charged to the scheme, it was obvious that the party would have to be small. The very limited accommodation in Colony vessels, in which the party would have to travel from island to island, led to the same conclusion. "What shipping could be made available for the scheme and what would it cost?" was most difficult to forsee, depending on when the scheme was to be undertaken. "How much would the explosive cost, where would it come from and how, and could any surplus munitions be obtained free?" "To what extent should local labour be used and how should it be organized?" These were some of the mass of questions I had to try to answer. My report fell into the category covered by saying "I am so sorry I have written such a long paper, I had not time to write a short one."

I recommended that the Sapper party should consist of two officers and six NCOs, amongst whom at least three would be divers. They would work in the Colony in 1962 and would attempt to tackle ten reef channels and the coral heads at Arunuka in eight months. They would be assisted by local labour as much as possible, and no heavy equipment or plant would be taken. These plans have, in fact, been implemented and as I write a party under Captain T. P. Hardy is starting work in the Colony. Perhaps I should have waited to write this paper until hearing whether or not the scheme worked.

After returning to Christmas Island we carried out various reef blasting trials to check the proposals. We learnt a great deal and were left with the feeling that there was no easy answer, but that suitable methods could be devised. I will not go into details of these trials here. As the scheme is carried out techniques will be established, and then will be the time to go into print.

I mentioned that at every island where work was proposed I asked "Does anyone ever get hurt by sharks or fish?" meaning octopus, barracudas, stone fish, eels and other horrors. Everywhere I received a rather amazed expression, as though it was a particularly odd question to ask, and the unconditional answer "No". I know that Captain Hardy's party are well prepared if, in the event, it turns out that, like the Chief of Kaubure at Gardner, they did in fact mean "Yes".

The Medway Bridge

By Major R. A. Merchant, RE

Introduction

The Medway Bridge forms part of the new 25-mile-long M2 motorway, which will leave the existing A2 main road 1 mile outside Strood and rejoin it 1½ miles beyond Faversham.

The motorway will eliminate traffic congestion in the Medway towns, which at present is choking the main route between London and Dover—especially during the summer months when holiday traffic streams towards the Channel ports and the north Kent coast.

The bridge crosses the River Medway between the City of Rochester and the Parish of Cuxton. The exact position of the crossing was dictated by the line of the Motorway which was tentatively fixed in 1954 by engineers from the Ministry of Transport and Civil Aviation, as it then was. Freeman, Fox and Partners were subsequently asked to report on the crossing, and several schemes in steel and concrete were investigated, the final choice being dictated by aesthetics as well as economics.

The report recommended that two bridge designs be prepared: one with the approach viaducts and main spans, in prestressed concrete; the other with viaducts in prestressed concrete and the main spans in steel. Eventually, tenders were invited for a prestressed concrete bridge as well as two steel designs of similar appearance—one all welded, and the other welded and bolted. The designs were all approved by the Royal Fine Arts Commission.

In August 1960, a tender for a prestressed concrete bridge submitted jointly by J. L. Kier and Company Limited, and Christiani and Nielsen Limited, was accepted at an estimated cost of £2,325,931, which was a few per cent cheaper than the welded and bolted steel alternative.

General Description of the Bridge

SPANS

The bridge, with its approach viaducts, has an overall length of 3,272 ft 6 in—nearly 2/3 mile. There are three spans over the river: a central span of 500 ft, to give the navigational clearance asked for by the Medway Conservancy Board, and two side spans of 312 ft 6 in, chosen for aesthetic and economic reasons.

The West viaduct has a total length of 1,350 ft and eleven spans; the East viaduct, a total length of 797 ft 6 in and seven spans. The West abutment passes over the main railway line between London and the north Kent coast, and is known as Shake Hole Bridge. Another railway line, between Maidstone and Strood, passes below one of the spans of the West viaduct.

BRIDGE DECK

The bridge deck is, for the most part, 113 ft 6 in wide. However, at the western end the width is increased to allow additional 12 ft lanes for acceleration and deceleration at the approach to the junction with the A228 Cuxton road.

The bridge carries two 24-ft wide carriageways with 1-ft margin strips, flanked by 8-ft hard shoulders. Bicycle tracks and footpaths are also included to cater for local requirements.

The carriageways are straight on plan, except for the last four spans of the East viaduct which lie partly on a 5 deg transition curve and partly on a circular curve of 2,865 ft radius. In the original design these curves were formed by skewing the piers and keeping the longitudinal beams at right angles to the cill beams at the top of the portal frames. This method of forming the curve would have necessitated constructing beams of varying lengths for each span, in fact, every beam would have been a different length. An agreement was reached between the contractor and the consultant whereby the piers were kept parallel. The curve was formed by offsetting succeeding piers by increasing amounts, towards the East abutment, from the centre line of straight portion of the bridge. All the beams could then be the same length but were inclined at an angle to the cill beams. This worked well and enabled the viaduct to be constructed without undue complications. The West viaduct has a vertical curve between the abutment and piers 9 and 10, apart from which the bridge is horizontal throughout its length.

The top of the horizontal deck is 116 ft above Ordnance Datum Level. Although this is higher than necessary for navigational clearance over the river, it avoids excessive earthworks on the adjacent sections of the motorway.

The bridge carries G.P.O. services and has provision for future lighting of the carriageway if required. Navigation lights on the main piers and at the centre of the 500-ft span will be provided to guide shipping using the river.

The Bridge Structure

ABUTMENTS

The West abutment is formed by Shake Hole Bridge, which itself has two abutments: the East one is of reinforced concrete cellular construction, whilst the West one is of mass concrete.

The East abutment consists of a buried two-bay portal frame with tapered columns on spread footing foundations. The back of the abutment has vertical joints to minimise stresses arising from the bending of the bridge seat beam.

When the East abutment has been completed the consultants ordered that the backfill from footing level to the top of the bridge seat beams, some 50 ft, should be granular, compacted in 6-in layers and achieve a dry density of 90 lb/cu ft. This compacted "plug" at the East abutment extends 20 ft either side of the width of the bridge and is 120 ft deep along the centre line straddling the East abutment. It was constructed to reduce the possibility of differential settlement between the approach ramp carrying the motorway and the end of the bridge.

VIADUCTS

Foundations

The viaduct piers rest on 22-in hexagonal driven piles of solid reinforced concrete, except where the hard chalk stratum was less than about 20 ft below ground level, when spread reinforced concrete footings were used in preference. The piles vary in length from 40 to 65 ft.

Piers

Each viaduct pier consists of a reinforced concrete portal frame, cast *in situ*, varying in height from 30 to 100 ft above ground level. The columns are rectangular on plan with a taper, in their longitudinal direction, of 1 in 60. At their tops, they measure 7 ft 6 in × 8 ft, or 7 ft 6 in × 7 ft, according to their height. The cross beams are 10 ft 6 in deep and either 6 ft 6 in or 7 ft wide; they have cantilevered sections at each end to reduce the maximum moments.

Superstructure

The viaduct superstructure is of beam and slab construction, simply supported for dead load and continuous for live load. For the most part, eight beams span between each pier, varying in length from 100 to 135 ft, with a maximum weight of about 190 tons. The beams are of precast concrete, prestressed with Lee McCall bars. The six inner beams are of I section, whilst the two outer ones are box beams to provide stiffness for the cantilevered section of the deck, and also to match the main spans over the river. The beams are generally placed at 12 ft 3 in centres and support a 9-in thick reinforced concrete deck slab, cast *in situ*. The slab is cantilevered out 10 ft 9 in beyond the edge beams to carry part of the bicycle track and footway. The beams rest on roller bearings at each pier, the viaduct structures as a whole being anchored at the abutments which are designed to resist all longitudinal forces.

MAIN RIVER SPANS

Foundations

The foundations to the two main river piers are reinforced concrete spread footings, 31 ft wide and 106 ft long, founded at a depth of some 45 to 50 ft below mean water level.

Piers

The two main river piers consist of reinforced concrete shafts, rectangular on plan and varying in thickness from 10 ft at the bottom to 6 ft at the top. The shafts are solid from the foundations to a height of 5 ft 6 in above high water level; above this they are of cellular construction. The tops of the piers are heavily reinforced and incorporate continuous hinges cast in high quality concrete. The hinges resist all longitudinal forces, whilst providing free articulation for the two side spans.

Superstructure

Each longitudinal half of the river-span superstructure, apart from a 100-ft gap in the centre, is carried by independent box girders of *in situ* concrete, cantilevered from the two main piers. Each girder consists of four 9-in thick webs, a 9-in thick top flange slab, and a bottom flange slab varying in thickness from 12 to 24 in. The top slab acts as the bridge deck and is cantilevered out 11 ft beyond the outer webs. The bottom slab is parabolic on the cantilever (central) arms and for part of the anchor (side) arms. The depth of the girders is 35 ft 6 in over the main piers, 9 ft at the ends of the anchor arms, and 7 ft 4 in at the ends of the cantilever arms. The girders are prestressed longitudinally and vertically by Lee McCall bars; transversely they are reinforced by mild steel bars.

The 100-ft gap in the centre is bridged by a suspended span of similar construction to the viaduct superstructure. The two ends of the span, however, are half joints—one pinned and the other on rollers.

SURFACING

The carriageways, marginal strips and hard shoulders are surfaced with 1½-in thick mastic asphalt with coated chippings; the bicycle tracks and footways are similarly surfaced with ¾-in thick asphalt. Precast concrete kerbs, set in mortar and secured by steel dowels, are provided at the edge of the bicycle track, and at the outer edges of the hard shoulders and carriageways.

The reservations between the carriageways and bicycle tracks are filled with concrete and paved with mastic asphalt.

Reflecting road studs will be provided on the carriageways along the lane markers.

BARRIERS AND PARAPETS

In the central reservation between the two carriageways, a crash barrier is provided consisting of steel channel posts supporting flexible steel guard rails on either side, and an anti-dazzle screen of expanded metal mesh on top.

The outer reservations, between the carriageways and bicycle tracks, are provided with barriers consisting of steel verticals supporting 4-ft high anti-climbing metal mesh on the bicycle track sides, and flexible steel guard rails on the carriageway sides. Solid reinforced concrete walls are provided in addition to these barriers where the West viaduct span passes over the Maidstone–Strood railway.

The footway parapets consist of rectangular steel tube verticals supporting a rectangular steel tube top rail—4 ft above the footway level—and panels of solid steel palings.

DRAINAGE

Drainage outlets are provided at the hard shoulders and, where required, at the carriageway kerbs. The outlets are connected to a drainage system under the deck which discharges all surface water through down pipes in the piers. The bicycle tracks and footways are drained by means of cast-iron channels through the reservations.

Investigation and Design

Soil Surveys

The soil surveys carried out in 1954 and 1958 showed that the River Medway runs in an old flat-bottomed valley in the Middle and Upper Chalk, which has been partly filled in by deposits of gravel, sand and peat. The chalk is heavily fissured and varies in consistency, depending on the degree of softening round the fissures. At the top, it consists of pieces of hard chalk in a soft weathered matrix, but lower down it is more compact and there is little of the weathered matrix. It was decided to found all the piers on this material, either on piles of spread footings—depending on the depth of suitable chalk below ground or water level—the footings to be constructed in cofferdams where necessary.

Foundations

For the viaduct pier foundations, piling was found to be practicable and tests were carried out on both bored and driven piles. In view of the difficulty in deciding when a bored pile had reached a chalk stratum capable of carrying the loads, driven shells piles were specified with a safe working load of 155 tons. However, the contractor finally chose the solid hexagonal piles which have been used. Loading tests have shown that these piles give a permanent settlement of about 1/10-in under 1½ times the working load.

With piers 1 to 5, at the end of the West viaduct, where spread footings have been used, excavations revealed a pronounced fissuring of the chalk formation, the main fissures running parallel with the river. It was therefore thought prudent to grout the formation for about 20 ft below the footings, to provide lateral stability to the blocks of chalk.

In order to avoid any underwater obstacles to shipping, the foundations to the two main river piers had to be below the river bed level, and it was found that spread footings of the dimensions used would be the most economical.

Main River Spans

In view of the possible settlement of the main piers, continuous river spans would have been uneconomical. A statically determinate structure was therefore chosen consisting of two balanced cantilevers and a suspended span. It was decided to use the independent box girders to simplify analysis and construction.

The girders were designed on the assumption that the contractor would use the cantilever method of construction, thus avoiding the use of temporary stagings in the navigational channel of the river.

Model tests on the girders were carried out by the Design Department of the Cement and Concrete Association at their Research Station at Wexham Springs, Buckinghamshire. The tests were carried out to check strain distribution and to investigate the possibility of buckling. A concrete model was made to a scale of 3/40, the total length being 15 ft, with 11/16-in thick webs and deck. The model was prestressed by 0.1-in diameter wires placed through ducts in the deck and webs. Loads were applied to simulate the Ministry of Transport's "abnormal load", which has a total maximum value of 180 tons, and also to simulate the effects of the self-weight in the structure. For the final test to failure, a very severe single-point load was applied to test the possibility of buckling. Failure occurred, without buckling, at a load equivalent to several times the total value of the "abnormal load".

Methods of Construction

VIADUCTS

Piles

The piles to the viaduct piers are cast on the site in banks of twenty-seven, with six layers in each bank. Each layer of piles acts as bottom formwork to the layer immediately above, waxed paper being used between to prevent the piles from sticking together. After seven days, the piles are lifted by travelling gantry and stacked for twenty-eight days before driving. The piles are driven with 6-ton single-acting steam hammers running in false leaders. The pile caps to piers, 6, 7, 8, 9, 10, 11 and 14 are below High Water Mark, and so the piles are driven inside sheet pile cofferdams. Where the mud below these caps is very soft, it is replaced by lean concrete to provide lateral stability to the piles.

Piers

Pier shutters, supplied by Stelmo Ltd., comprise two steel L-shaped sections, 13 ft high with 2-ft deep top and bottom rings. Each cast of column is 15 ft high and the 2-ft rings are interchanged on succeeding casts, the top ring on one cast being left behind when the shutter is stripped to become the bottom ring on the next lift. Adjustment for the 1 in 60 batter on two faces is made where the ends of the L-shaped pieces butt.

The top of the columns are chamfered on two faces and form a seating for steel collars which serve as supports for the crossbeam formwork during construction. The collars carry a maximum load of approximately 280 tons each and are prestressed with 4 Lee McCall bars.

The side formwork, supplied by Acrow Ltd, to the crossbeams consists of plate steel girders designed to carry the vertical loads and to resist lateral pressure from the vibrated wet concrete. The side formwork consists of six panels, each 14 × 40 ft and weighing 6.5 tons. They are raised into position on the collars by derrick or crane and held in position by a temporary erection girder until top crossbracing is in position.

The formwork to the beam soffits is then erected, the reinforcing cage fixed in position, and the concrete of each beam placed in one operation. The maximum deflection registered was 3/16-in when casting from over one column and working along the beam on an inclined face of concrete.

Superstructure

The viaduct beams for the superstructure are made in casting yards at the shore end of each viaduct. The soffit formwork to the beams is carried on rolled steel joists in the longitudinal direction; these in turn are carried by concrete cross walls at about 6 ft centres. Packings between the walls and the rolled steel joists are made sufficiently flexible to permit movement caused by vibration during concreting, shrinkage and elastic shortening.

The end blocks of the beams, which are congested with reinforcement and ducts, are cast first, in a horizontal position, to facilitate compaction of the concrete. This also ensures that the concrete in the end blocks is older than that in the remainder of the beams, allowing earlier prestressing and handling.

After curing, the end blocks are positioned on the casting beds. Mild steel reinforcing cages, together with the prestressing ducts and tendons are then fixed in place, the latter supported on preformed steel locating frames. The side formwork is of steel with brackets welded on at intervals to hold the external vibrators. The concrete is placed by bottom-opening skips, lifted by a derrick which also handles all other materials and formwork in the yard.

The remainder of the I beams are cast in one operation, the box beams in two. The U sections of the box beams are cast first and subsequently the top slabs, the soffit formwork to these being left inside the beams. After striking the side forms, two bars are stressed to counteract shrinkage. After three days sufficient bars are stressed for the beams to be jacked, rolled sideways on steel balls and stored. Final stressing is carried out after twenty-eight days, and all the ducts subsequently grouted. Gamma ray tests are made to check the efficiency of the duct grouting.

The completed beams are picked up from the storage yard and carried to within reach of the launching equipment by portal gantries which run on tracks, placed initially on the approach ramps to the abutments, and subsequently on two beams of a completed span. The launching equipment consists of a steel trussed girder, triangular in section, with a front tower support and rear leg supports. The girder is travelled forward on a bogie under the leg supports, with the tail end of the girder counterbalanced by the first box-beam for the next span to be launched, and the main part of the girder cantilevered forward from the legs. The launching bogie runs on top of the inner two I beams already placed in the previous span. When the forward tower has reached the pier ahead the nose is jacked down, the bogie removed and the rear legs packed. The concrete beams are transported across the span on two carriages running on the bottom chord of the girder, then jacked down and rolled sideways into position on steel balls.

When beams on adjacent spans have been placed in position, short stressing bars connecting brackets below the bottoms of the beams are stressed, and the beams are jacked down into permanent bearings. The *in situ* deck slab is now cast, with the exception of short sections over the piers which are left un-cast to preserve the simply supported state of the beams. The final stage is the casting of diaphragms between the beams together with the remaining portion of the deck slab.

MAIN RIVER SPANS

Foundations

Excavations for the river pier foundations have been carried out inside steel sheet pile cofferdams, and for most of the work, grabs of various types have been used. In the final stages of excavation, the material immediately above formation level and that clinging to the sheet piles was loosened by water jets guided by divers. Final preparation of the formation was completed by divers operating an air lift, which brings up the slurry and loose chalk. Large lumps of chalk had to be manhandled into the grab.

The fissuring of the chalk made de-watering impossible. The cofferdams were therefore sealed by 21-ft thick plugs of concrete placed under water by bottom-opening skips of 4 cu yd capacity. For bottoming and plugging, the pier foundations were divided into five sections each by placing precast concrete panels vertically across the cofferdams and holding them in position by "Universal" steel beams. After de-watering the cofferdams, the top of the underwater concrete was cleaned and levelled off; the reinforced concrete slab was then cast on top in the dry.

Piers

The main river piers are cast in 8-ft lifts using timber formwork with horizontal grooves at 4-ft centres to mask construction joints and shutter bolts.

Superstructure

The main river-span superstructure is constructed in two longitudinal halves, the system of construction being identical in both cases.

The girder sections over the piers are constructed first and are partly of precast concrete units supported on steel beams spanning between the main piers and temporary steel towers located in each shore span.

Each girder is then built out in 10 ft sections on either side of a pier, care being taken to keep a downward reaction on the steel tower to guard against overbalancing. Vertical timber boarding is used for the outside of the girders; plywood panels are mainly used for the inside. Formwork for each stage is supported from a cantilevered carriage on either side of a pier, anchored to the previously completed sections. Each section is cast, allowed to harden and then stressed by Lee McCall bars. Stresses in the girders are checked at every stage of construction to ensure that they are within permissible limits during erection as well as under working conditions.

As the cantilevered construction proceeds and the two carriages get farther away from the pier, the out of balance moments grow larger and the reactions on the steel tower become excessive. A second tower is therefore erected, approximately 160 ft from the end of the anchor span. As soon as this tower is passed by the cantilevered carriage in this span, the supports to the girder are transferred from the first to the second tower. The cantilever arm is completed first, being only 200 ft long as compared to the 312-ft long anchor arm. The cantilevered carriage for this section is then dismantled and used again for the construction of the anchor arm of the second half of the bridge.

The cantilevered construction of the anchor arm is continued as far as the negative moment over the tower, in relation to the cross section of the bridge, will allow. A third tower is then erected, and a controlled reaction introduced by means of hydraulic jacks.

The construction of the anchor arm is next completed, the reaction over the third tower being carefully controlled so that the bending moment on the second tower should not be in any way increased.

When the structure is complete, there are only positive bending moments in the last 75 ft of the anchor arms; prestressing tendons are therefore placed in the bottom slabs. It is necessary, for construction purposes, to introduce some extra top tendons in these sections of the anchor arms. These extra tendons are finally removed, the girders being then simply supported by hinges at the main piers, and rollers at the shore piers.

The 100-ft suspended span over the centre of the river is cast and launched in the same way as the viaduct superstructure, being of similar construction —except that the beam soffits are curved.

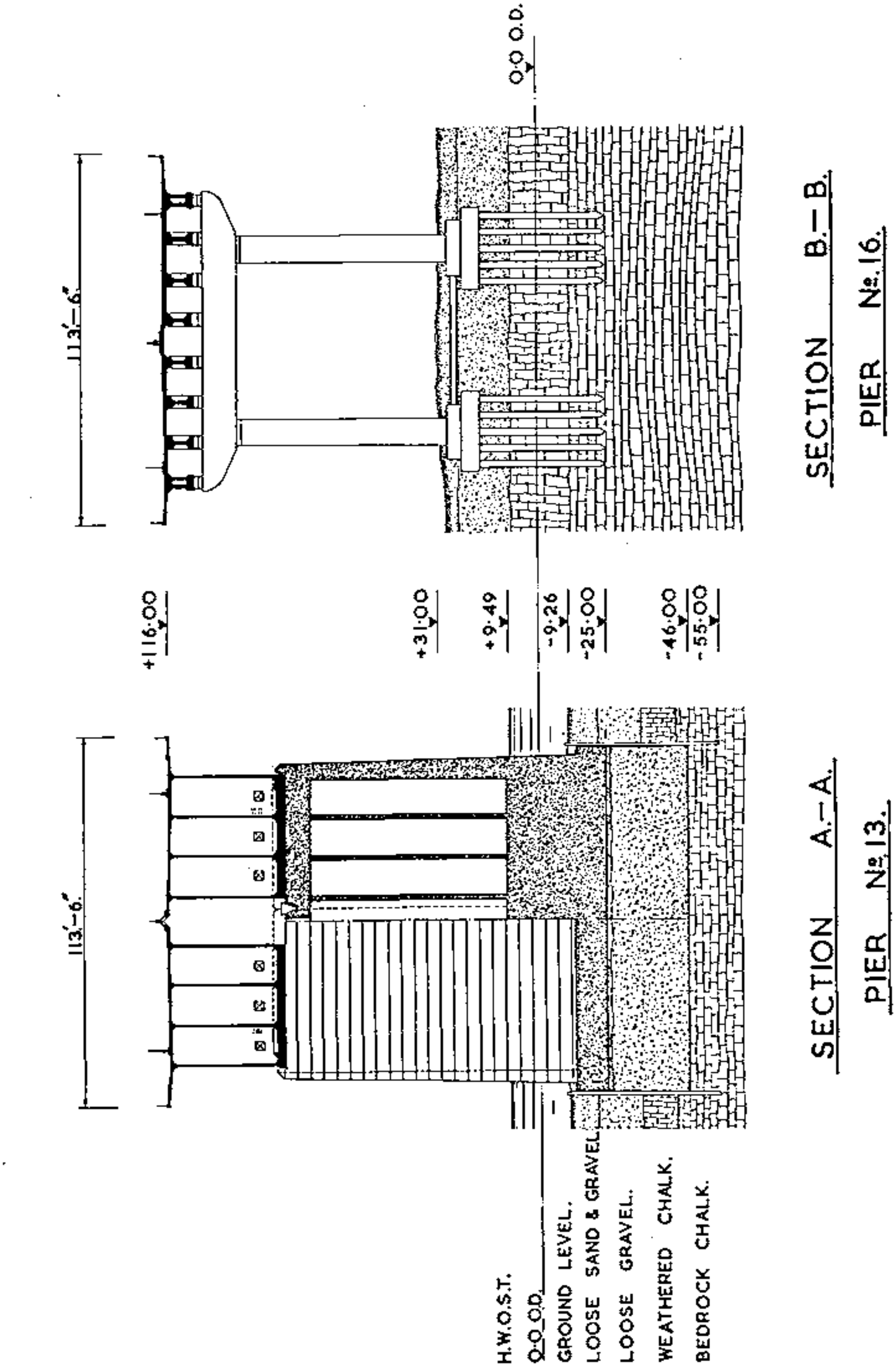
Statistics

Overall length of bridge, excluding embankments, 3,272 ft 6 in; main span, 500 ft; anchor spans, 312 ft 6 in; width of bridge 113 ft 6 in–137 ft 6 in; height of road surface above mean tide level, 116 ft; number of viaduct spans, 18; number of precast beams, 162; maximum weight per beam, 195 tons; maximum length per beam 135 ft; total number of piles, 498; length of piles, 45–65 ft; weight of piles, 9–13 tons; design load per pile, 155 tons; maximum load on pile cap, 2,600 tons; total weight of mild steel, 5,420 tons; total weight of concrete, 118,000 tons; total length of prestressing bar, 187 miles; working load per bar, 47 tons; maximum prestressing force at the main piers, approximately 26,000 tons. Average concrete strengths (during first 15 months)—Class C and D (O.P.C.) Mix 1: 6.6—(3 days), 3,835 (7 days), 5,255 (28 days), 6,800 and (90 days), 7,575. Class A (O.P.C.) 1: 4.0—5, 975, 7,360, 8,560 and 10,180 respectively. 1: 4.5 + additive—6,155, 7,200, 8,200 and 10,200 respectively.

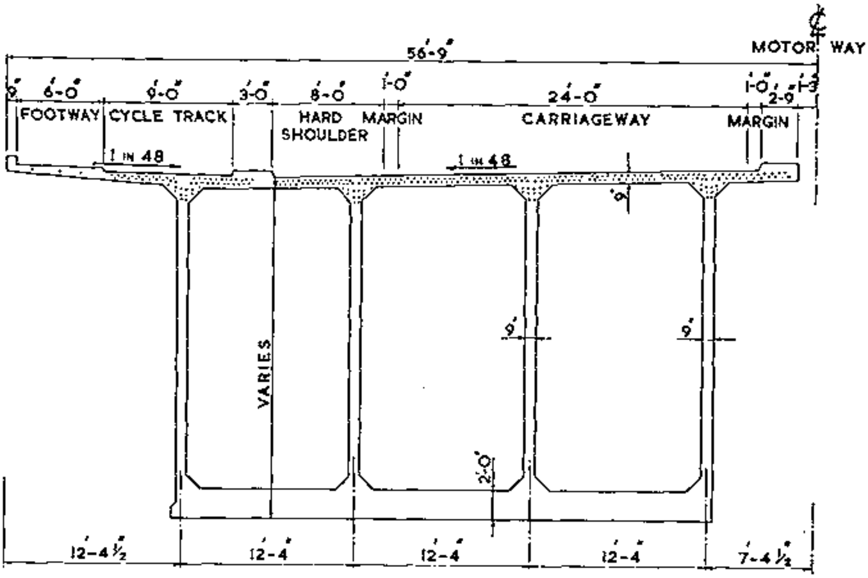
Progress to Date

As a student on No. 8 Long Engineering Course, I was attached to Kiers on the Medway Bridge site on 12 March 1961. Apart from one cill beam and three or four 15-ft column lifts constructed whilst I was on leave, the East abutment, pile caps, columns and cill beams on the East bank were my responsibility. They were completed by November 1961 when I handed over the Stelmo and Acrow shutters to Major Storr who commenced construction on the West bank. Major Storr and I were most fortunate in obtaining such a degree of responsibility during our attachment and gained very useful practical experience in large scale civil engineering.

Since work started in the autumn of 1960 on this prestressed concrete structure—the largest of its kind in the world—considerable progress has been made. Construction of the viaducts is well advanced. The building of the main river piers and the first stage of the main spans has been completed. Work on the cantilever erection of the main spans for one half of the width of the bridge is nearly completed. Ten foot sections are being cast at about weekly intervals on each cantilever carriage.

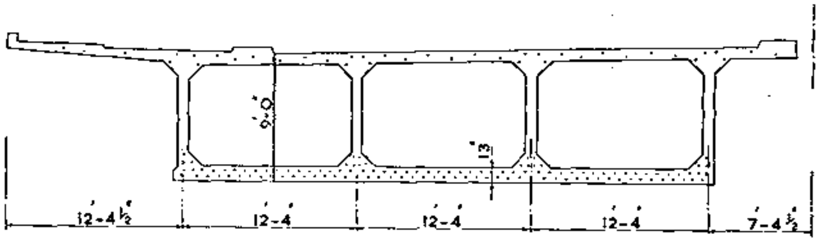


113'–6"
113'–6"
0·0 O.D.
+116·00
+31·00
+9·49
-9·26
-25·00
-46·00
-55·00
H.W.O.S.T.
0·0 O.D.
GROUND LEVEL.
LOOSE SAND & GRAVEL.
LOOSE GRAVEL.
WEATHERED CHALK.
BEDROCK CHALK.
SECTION A.–A.
PIER No 13.
SECTION B.–B.
PIER No 16.



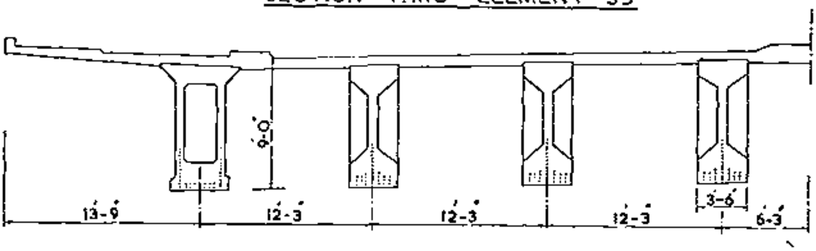
RIVER SPAN CANTILEVER ARM

SECTION THRO' ELEMENT 'd'



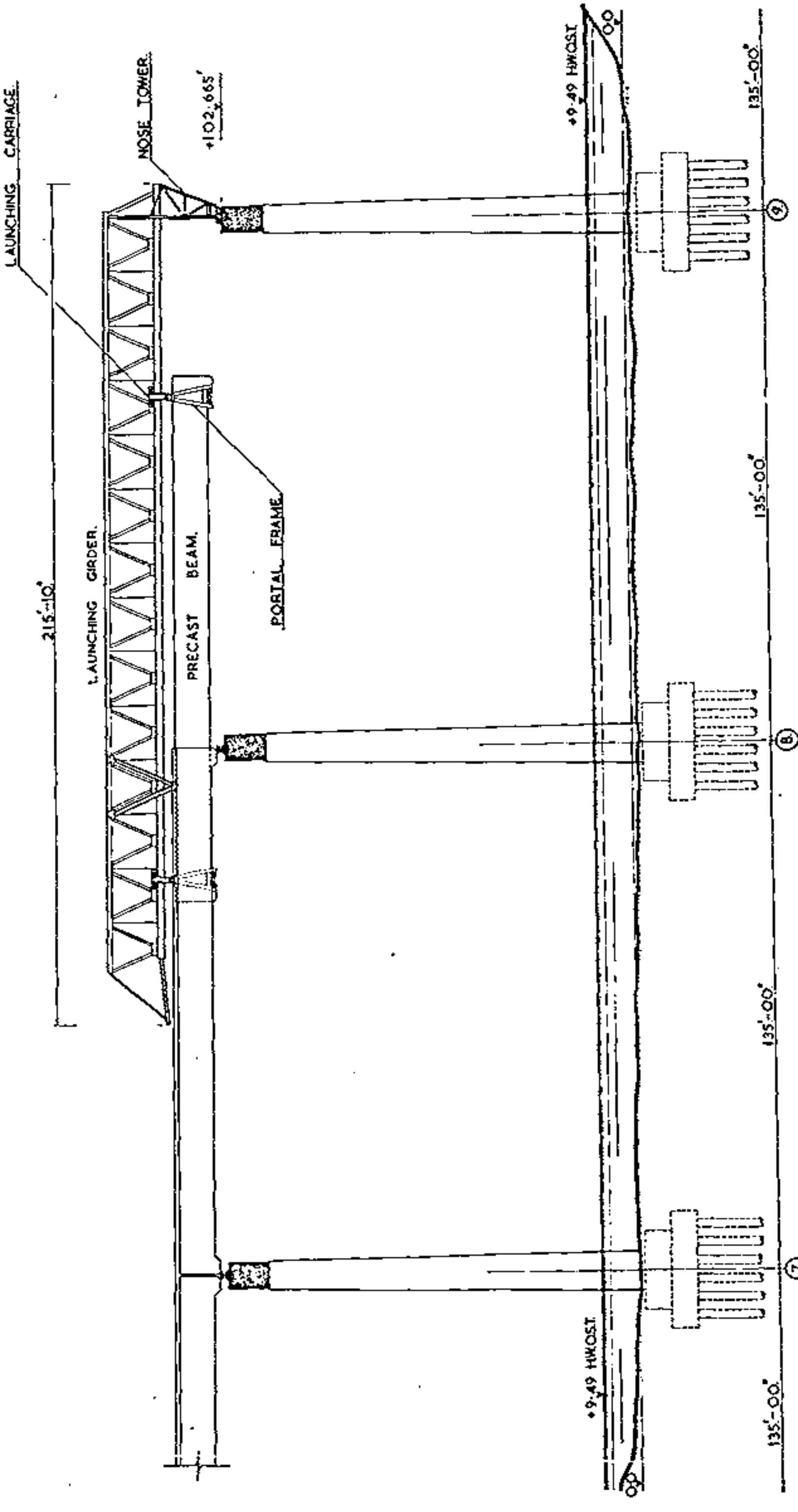
RIVER SPAN ANCHOR ARM

SECTION THRO' ELEMENT '35'

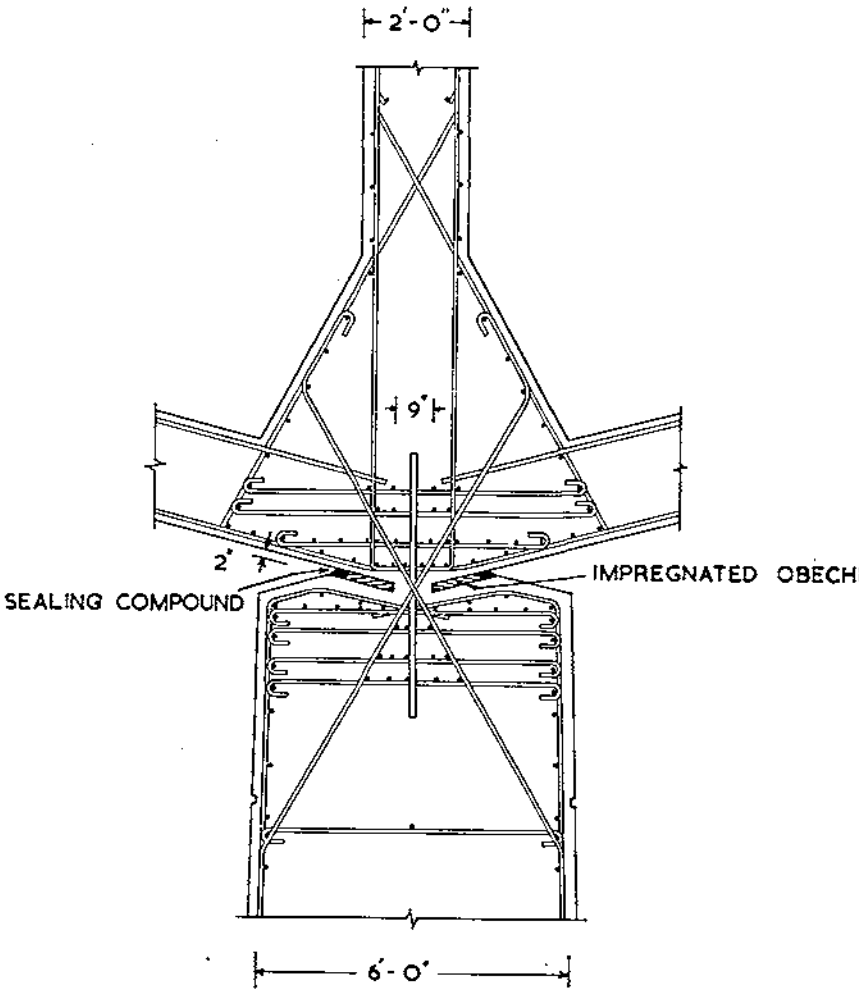


VIADUCT SPAN

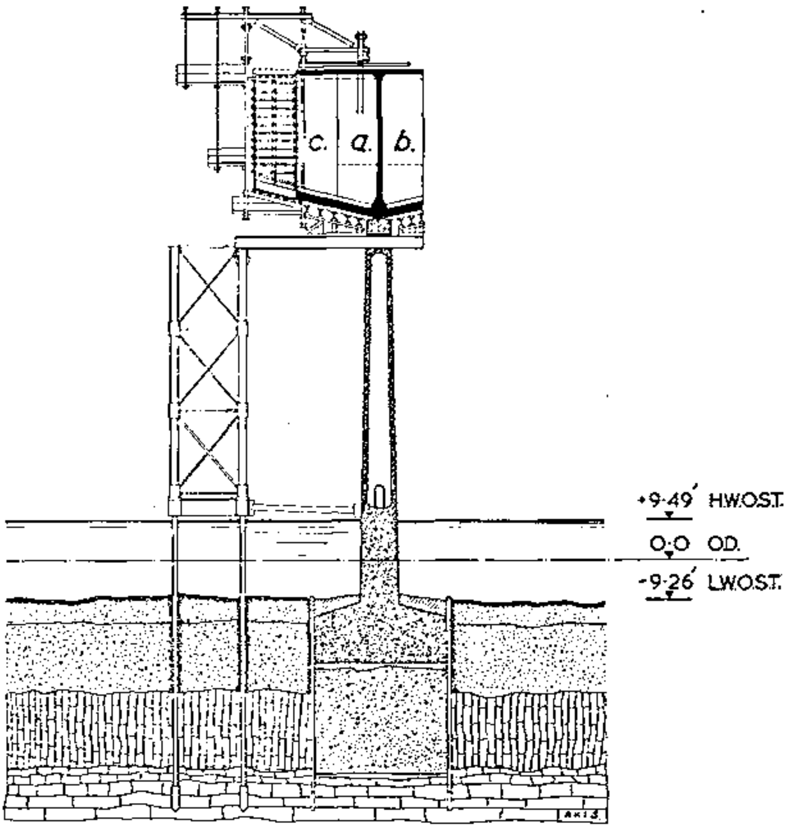
SECTION THRO' MID SPAN



LAUNCHING OF PRECAST BEAMS.

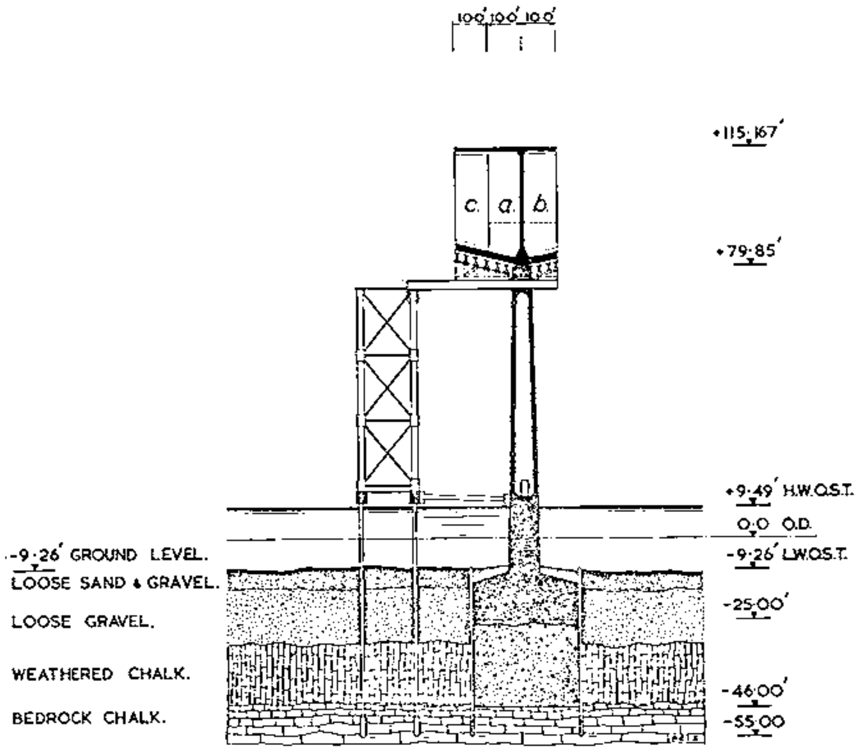


MAIN PIERS
SECTION THROUGH HINGE



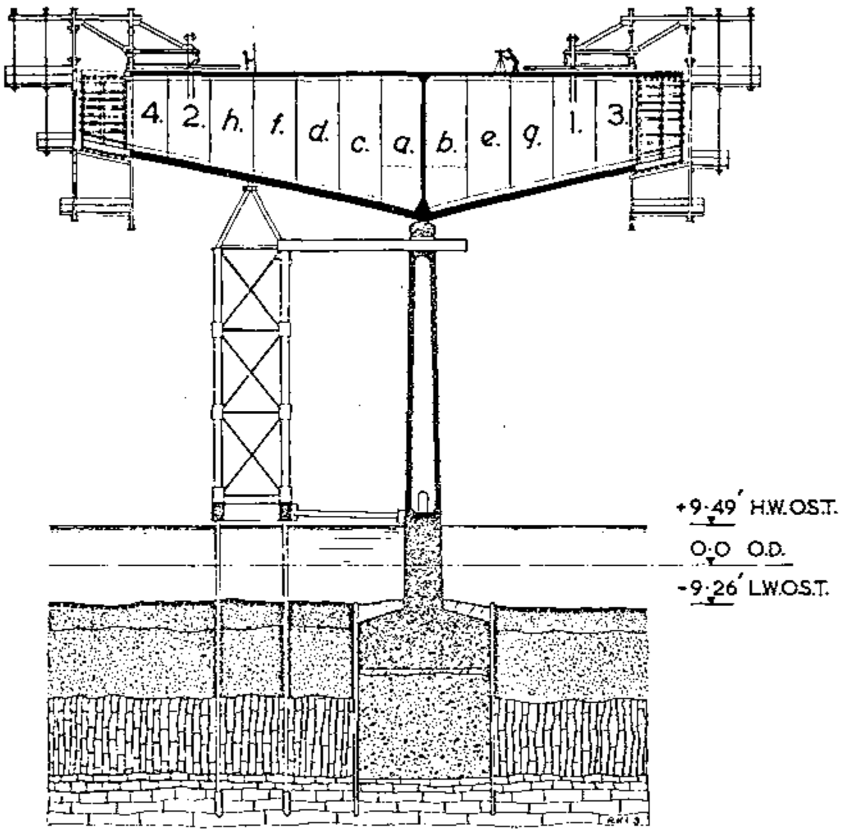
2nd STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



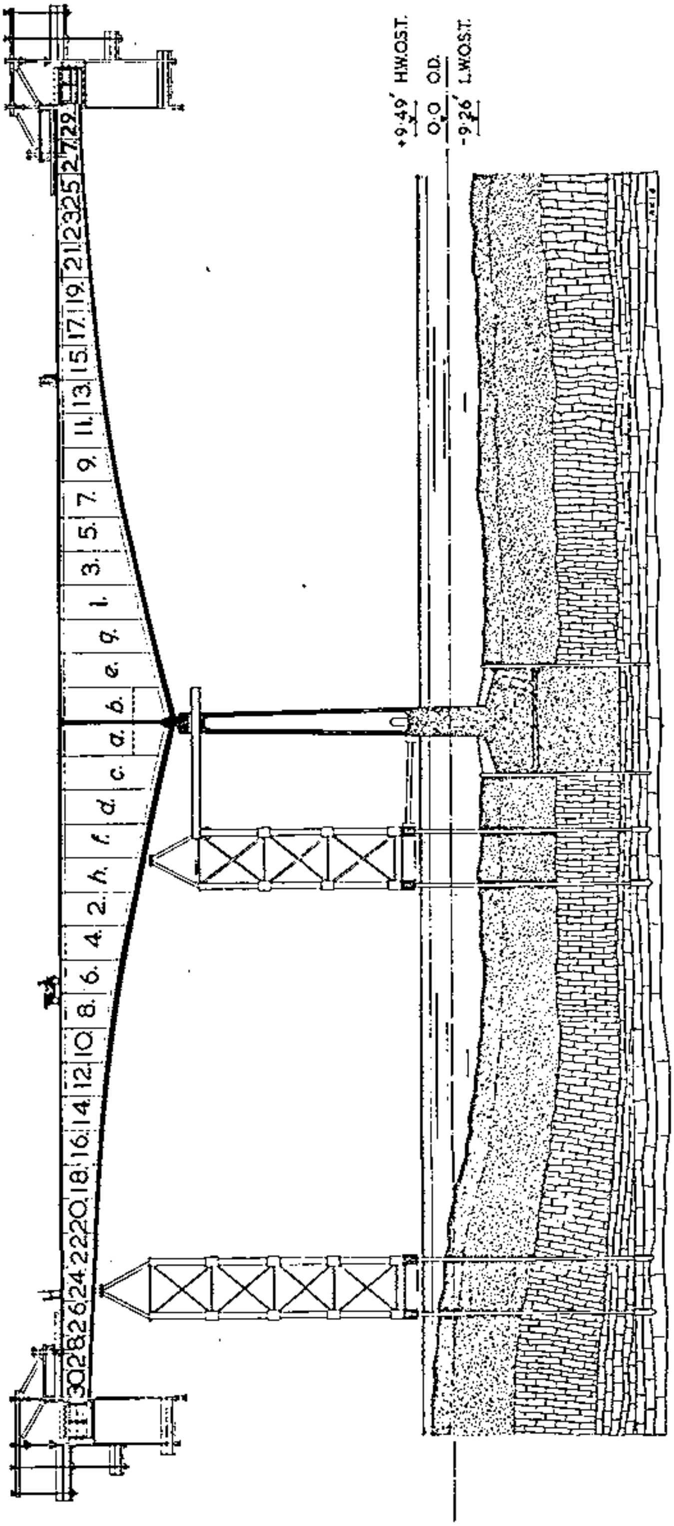
1st STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



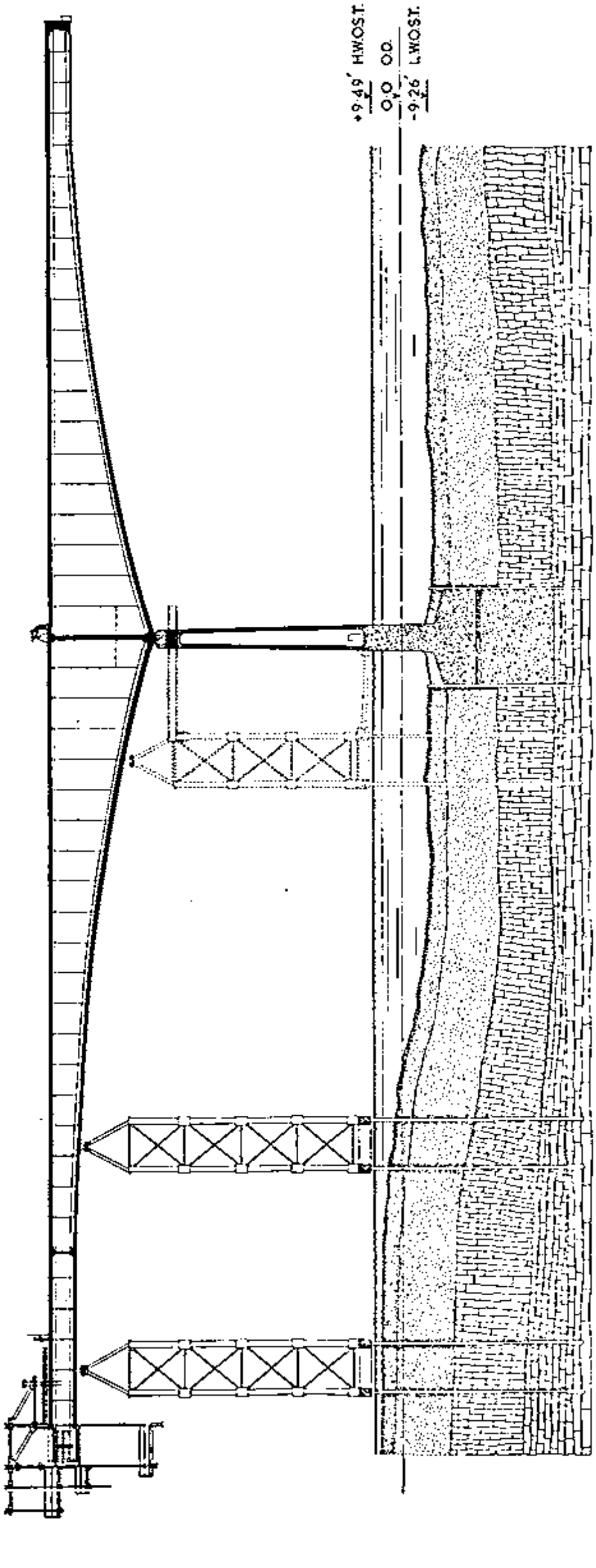
3rd. STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



4th STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



5th STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.

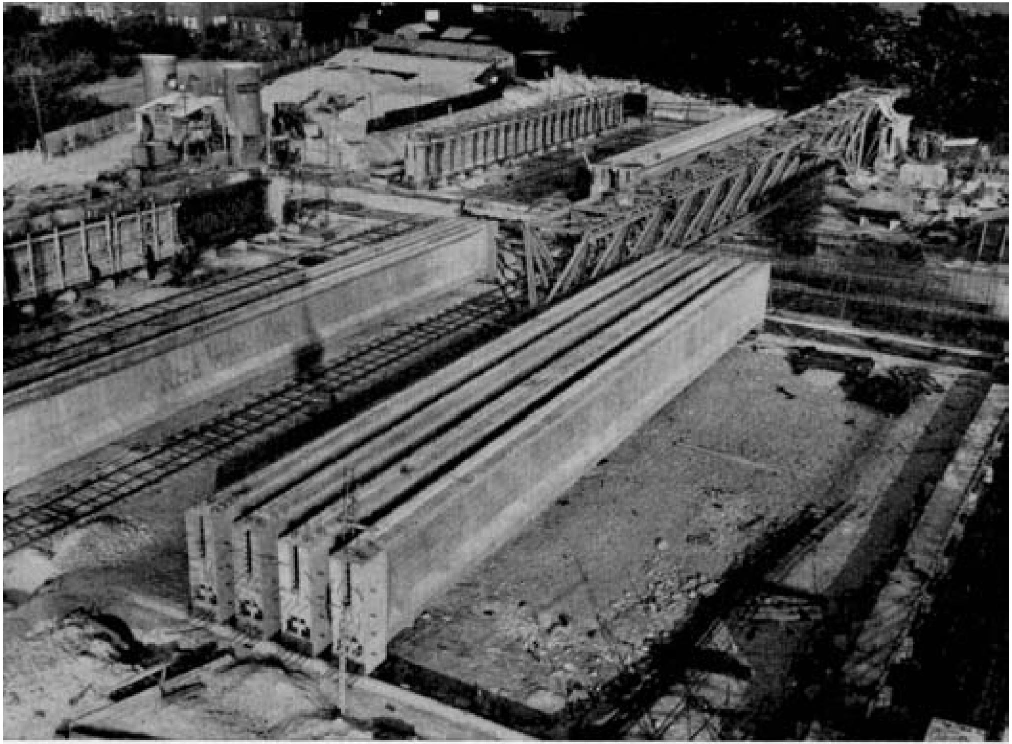


Photo by C. E. Howe Ltd. Chatham

Photo 1. Beam casting yard, east bank.

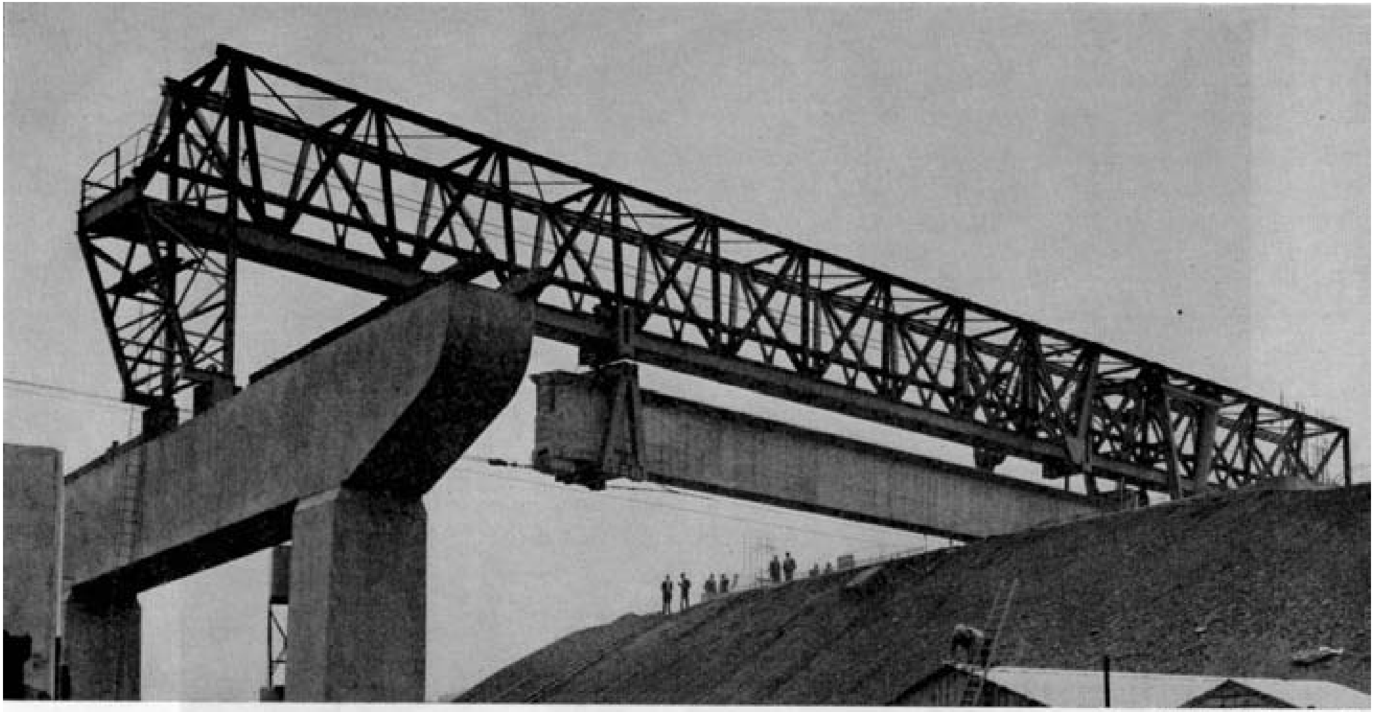


Photo by C. E. Howe Ltd. Chath

Photo 2. Beam launching on viaduct span.

The Medway Bridge 2

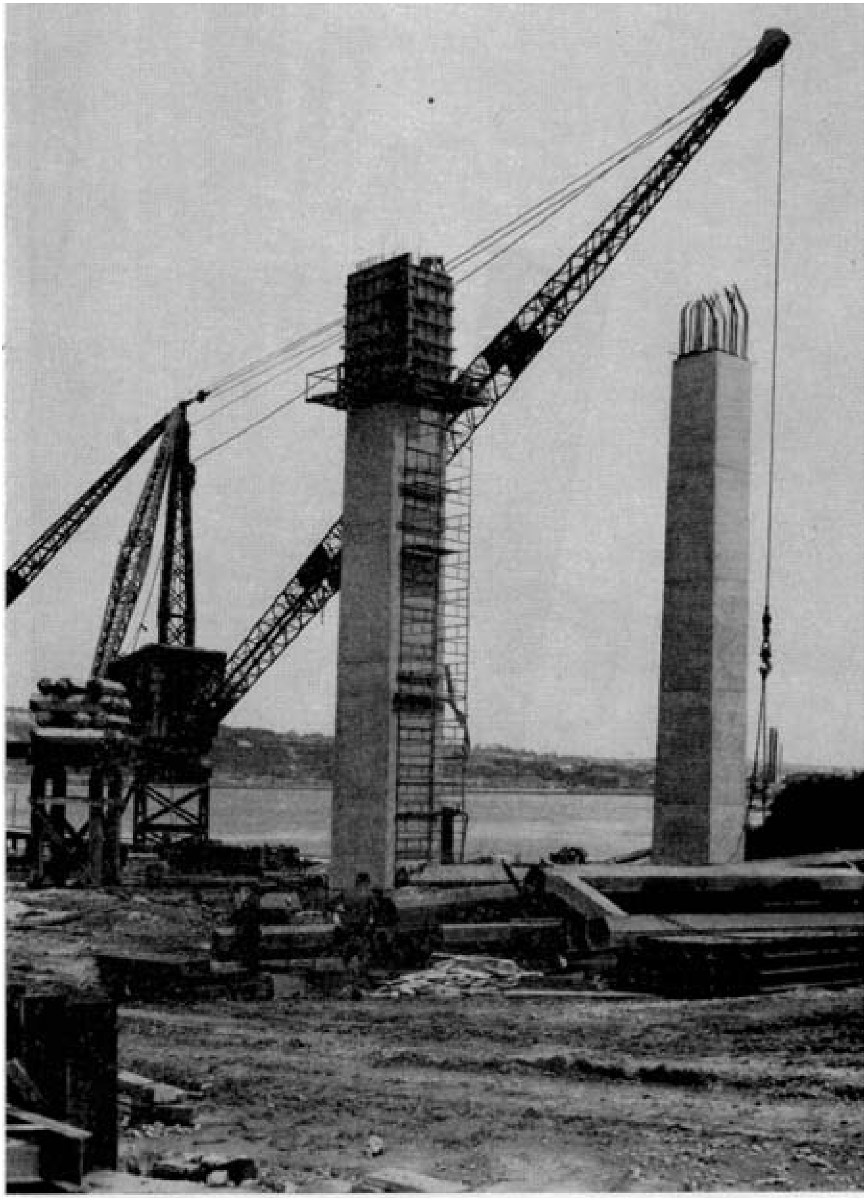


Photo by C. E. Howe Ltd. Chatham

Photo 3. Column casting.

The Medway Bridge 3

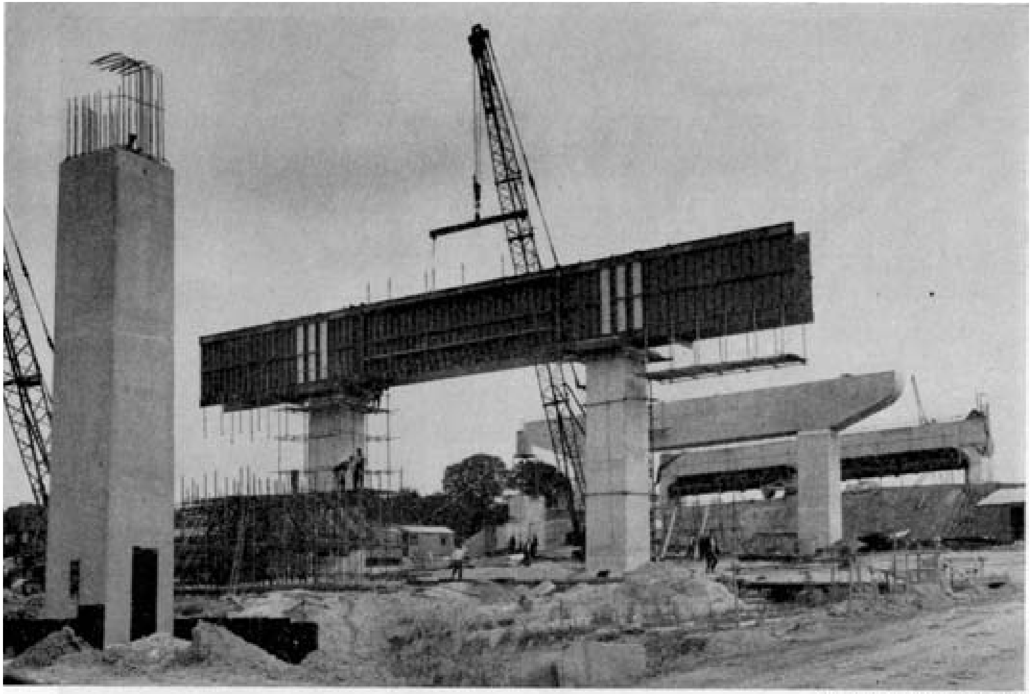


Photo by C. E. Howe Ltd. Chatham

Photo 4. Cross beam formwork.

The Medway Bridge 4

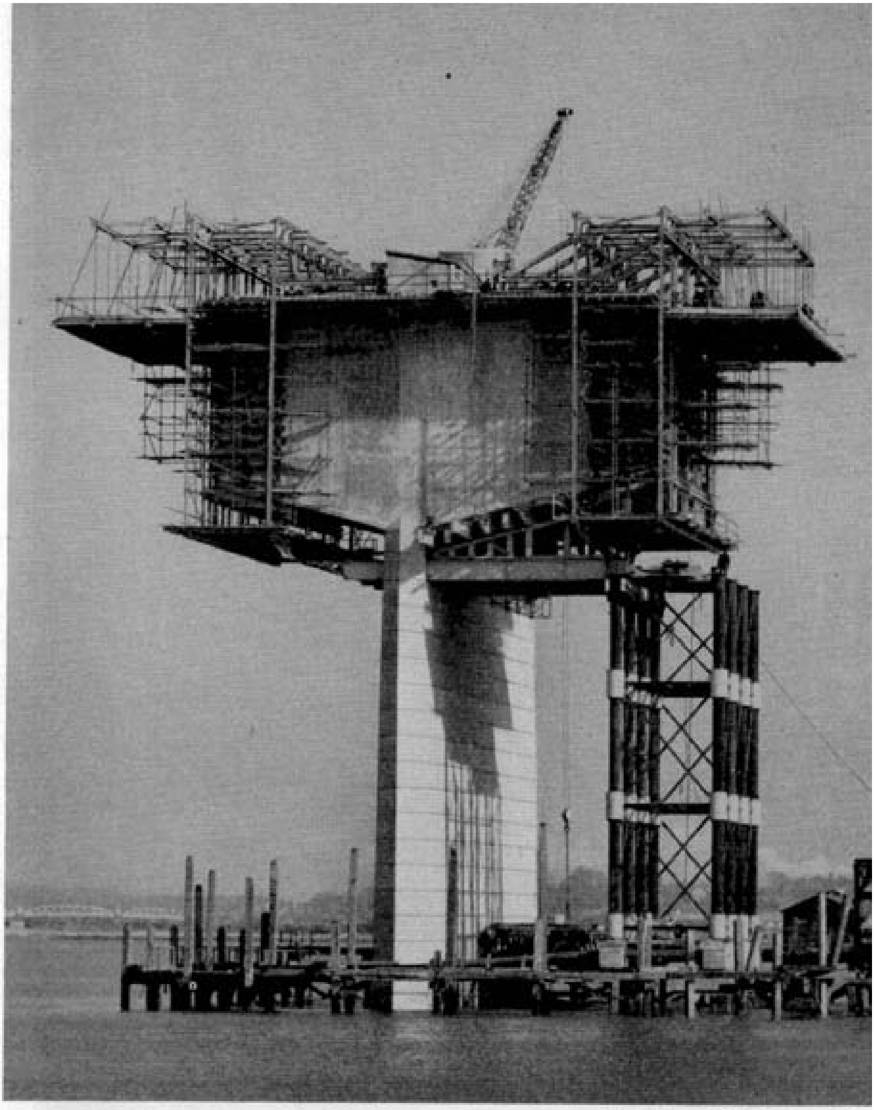
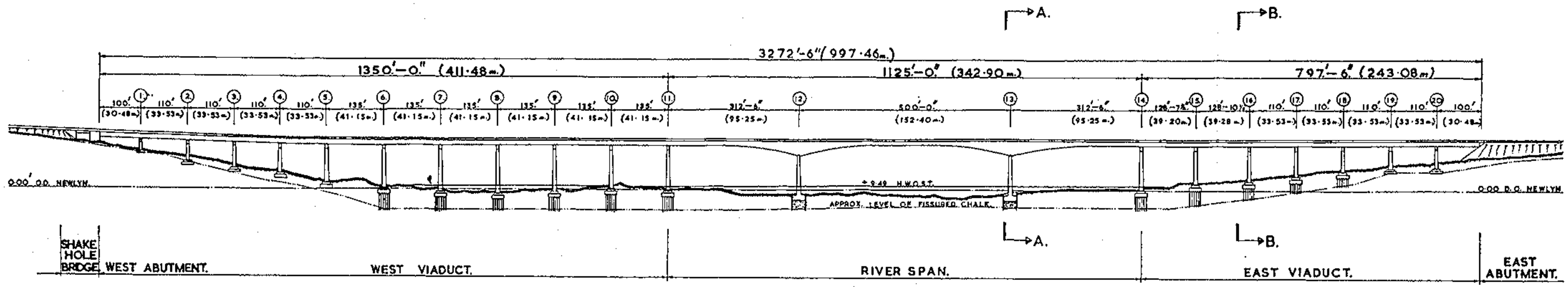


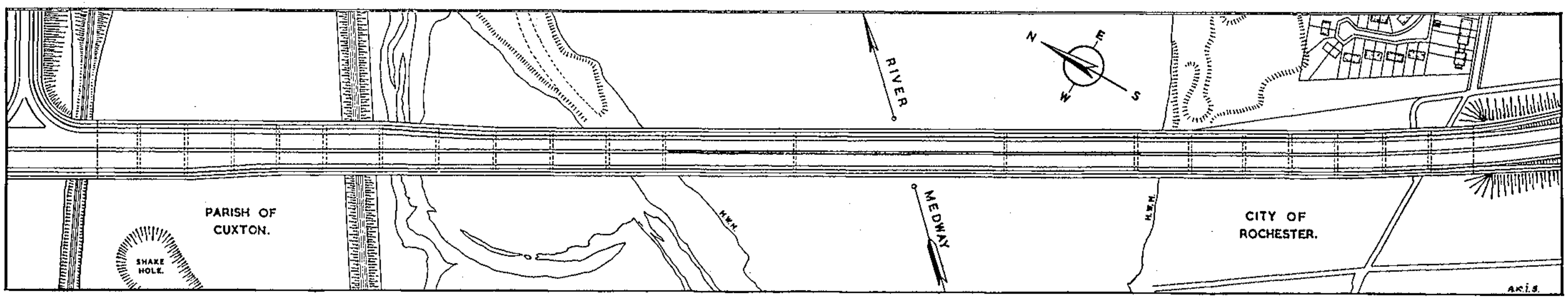
Photo by Leonard Hill, Rochester, Kent

Photo 5. River Pier with Cantilever Carriages in operation and Temporary Steel Tower to keep bridge in balance during construction.

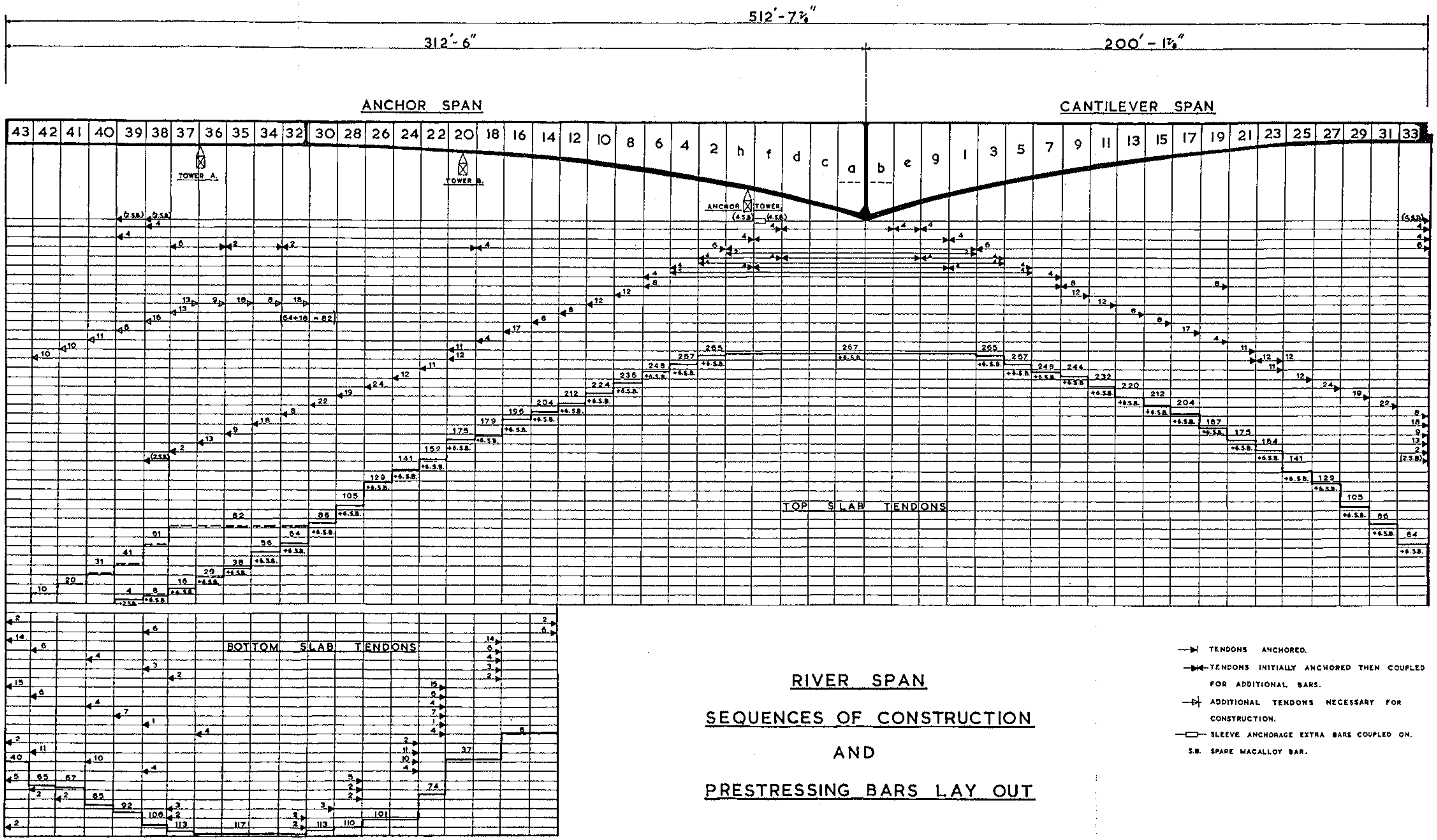


MEDWAY BRIDGE

ELEVATION.



PLAN.



RIVER SPAN

SEQUENCES OF CONSTRUCTION

AND

PRESTRESSING BARS LAY OUT

TENDONS ANCHORED.

TENDONS INITIALLY ANCHORED THEN COUPLED FOR ADDITIONAL BARS.

ADDITIONAL TENDONS NECESSARY FOR CONSTRUCTION.

SLEEVE ANCHORAGE EXTRA BARS COUPLED ON.

S.B. SPARE MACALLOY BAR.

Correspondence

Linton Developments Limited,
R. A. Linton, MA, AMIEE,
Three Gables,
First Avenue, Felpham,
Bognor Regis, Sussex.
12 June 1962

The Editor,
The RE Journal,

Dear Sir,

CIVIL ENGINEERING GRADUATES IN THE ARMY

Colonel Cartwright Taylor's article on "The Opportunities for Civil Engineering Graduates in the Army" gave little indication of the very small amount of construction work carried out by the army in peace time.

I joined the Royal Engineers as a graduate, expecting full use to be made of my expensive education, but first I received further practical training at the SME. Came the war and I was able to use much of what I had learned at the SME, but I felt that my MA degree was wasted.

Regimental duty makes virtually no demands on a University education, and I volunteered for a long E & M Course. So I was further educated, and at least I made a little use of all this training on E & M work in the Middle East.

I eventually retired to form my own construction company, and in three years I have done more useful work than I did in twenty-two years in the army.

In my view it is essential that the Royal Engineers take on a public works responsibility in peace time. The US Corps of Engineers carry out large schemes on river works, irrigation etc, and the obvious counterpart in Britain is coast defence works. The backlog of work on groynes and sea walls in this country is enormous, and it could provide the Corps with interesting, varied and extremely skilled work year in and year out.

Alone among the technical Corps, the Royal Engineers seek to maintain professional ability by training, without properly engaging in the work of their trade. Yet a man only attains ability by the confidence which experience brings him. If it is proposed to attract Civil Engineering Graduates into the Corps as Colonel Cartwright Taylor's article implies, then they must be provided with something useful to do.

Yours faithfully,
(Signed) R. A. Linton, Major, RE, (retd.)

Note by Editor

With an All Regular Army it will be possible to devote more time to carrying out engineering projects for civil authorities than was possible in the days of National Service, and it is War Office policy to increase the amount of engineer works undertaken by the Corps.

A misconception perhaps exists that, because Works Services have been "civilianized", the Royal Engineers spend most of their time on field engineering. This is far from the case, and the following major works projects are but a few of those carried out by the Corps during the past few years:—

Bukit Terendah Camp, Malacca, Malaya

This was a brigade cantonment built at a cost of some nine million pounds on a site of secondary jungle and rubber. The construction was placed in charge of a military CRE (Works) and staff; the preliminary work was carried out under the CRE using directly employed labour and plant. The buildings were standard FARELF designs and were erected by local contractors under RE supervision.

Training Area, North Borneo

This project was started in June 1959 and an engineer squadron group has been employed on the task for over two years, British, Gurkha and Malayan Field Squadrons have all taken a hand. The project included the provision of accommodation and auxiliary services for a Brigade Group, the construction of landing hards and wharves to open up a heavy L of C via Usakan Bay and the Abai River, the provision of 11 miles of road and 16 miles of tank tracks including concrete road crossings and turning slabs and hard standings, the realignment and improvement of several miles of road between Jesselton to Kota Belud, the provision of a number of Bailey Bridges and landing strips for light aircraft.

Work is at present in hand on the construction of a Beverley airstrip, the provision of additional tracks within the jungle training area to permit access by wheeled traffic, the provision of a radio link and the improvement of the present personnel accommodation and amenities for the troops.

Gurkha Cantonment, Dharan

This cantonment in Nepal, including some 27 miles of road over paddy fields and through jungle, costing several million pounds, was also a Royal Engineer project.

Kahawa Cantonment, Templer Barracks, Nairobi

This is a cantonment for two infantry battalions, together with married quarters, church, schools, cinema, clubs, swimming pool, gymnasium and sports fields. The project will cost over three million pounds. The site supervision is in the hands of a military CRE (Works) and his staff, and the cantonment is being built by UK contractors.

Christmas Island

The Royal Engineers were responsible for the provision of all living accommodation, water and power supply, roads and airfields and port facilities besides all other technical structures required for the test firings and the assessments of their effects. The work was completely military and organized by a Chief Engineer and his planning and resources staff, supported by a reinforced Corps Engineer Regiment. At one time a rate of road construction of 1 mile a day was reached which involved the running of a Starmix 4D asphalt plant and the production of 100 tons of coral aggregate a day. An asphalt surfaced lagoon mud airfield, capable of taking V bombers, was constructed entirely by RE labour and military plant.

Plashetts Bridge, Northumberland

This bridge over the River North Tyne near the village of Plashetts in the Border Forest Park of Northumberland was built by 48 Field Squadron of 38 Corps Engineer Regiment for the Forestry Commission. It replaced an old 130-ft Bailey bridge. The bridge, an RSJ and reinforced concrete slab deck bridge with three spans of 40 ft, 50 ft, and 40 ft on concrete piled piers and concrete abutments, was designed by a Sapper subaltern, and the whole project was carried out by Squadron labour using service plant.

Otterburn Road, Northumberland

Two miles of road across peat bog moorland country on the WD ranges at Otterburn and a Class 100 prestressed concrete bridge were built as a troop trial. The road was designed and constructed by 38 Corps Engineer Regiment in two summer periods of two months using military plant. The dense tar surfacing was purchased but the remainder of the work, including the provision of quarried stone, was done by the Royal Engineers.

Other Activities

Royal Engineer officers have taken a full part in the following projects:— Nuclear Power Stations at Dungeness, Sizewell and West Thurrock; the British Railways'

Euston Development Scheme; the Tyne Tunnel; the Medway Bridge; LST hards in Cyprus for the Admiralty; British Petroleum Middle East POL Projects; the Devon Island Expedition; the Canadian PWD Highway Division in the Yukon; the Snowy Mountains Authority in Australia. Additionally about eighteen RE officers each year are attached to civilian engineering firms engaged on major projects as part of their Long Engineering Course.

Finally the Royal Engineers constantly find themselves called upon suddenly to meet demands for help in local disasters and to carry out a wide variety of civil engineering tasks; famine relief work in Kenya, hurricane relief work in British Honduras, flood relief in Hamburg and storm and flood damage in this country are but a few recent examples.

The Editor,
RE Journal.
Dear Sir,

Major J. McDowell, R.E.
3 Long E and M Course
RSME, Chatham.
13 August 62.

E & M ENGINEERING IN THE CORPS

(400 vs 50/60 cycle AC Generators)

I was delighted to see Major Tree's rejoinder in the March issue of the Journal to my doubts as to the wisdom of changing from an alternating frequency of 50/60 to 400 cps for GS generators since I know him to be an electrical engineer of wide experience. However, I am relieved to hear that the proposal has not yet been adopted. Before I explain why, let me assure Major Tree that I do not view this problem from what he terms the "Base or L of C" aspect, but primarily from that of combat zone units of all arms who need power in the field and from practical knowledge of their technical requirements.

Nevertheless, these same units are to be found at time in the communications zone and elsewhere, performing tasks which require power, and this factor must not be ignored even though it is secondary to that of winning the battle.

If I felt that the change was in any sense a battle-winning factor I would support it but in fact I am sure it is not, and for that reason I maintain that "out of battle" requirements thereby assume a greater importance.

The power needed in the field can be likened to water supply. Formations need water which is drinkable though not of Metropolitan Water Board standards. They also need small amounts of distilled water for batteries, photography and medical needs. No one would dream of insisting that all water supplies should be of this purity.

Similarly, a great proportion of the power required in the combat zone for lighting, battery charging, portable tools, medical refrigeration, heating, etc., could be of a very "coarse" nature and DC or AC of any frequency would suffice for this. A smaller proportion, for use in electronic complexes, is needed in a more "exotic" form, i.e. with close voltage and frequency regulation. In both cases, the aim is to produce maximum power for minimum weight of generator.

As Major Tree points out, the proportion of "exotic" to "coarse" power required in the combat zone is increasing. This is an unfortunate result of the retention by the Army of thermionic valve equipment instead of making the change to transistorised and other solid state electronics.

The circle is a particularly vicious one. Thermionic valve transmitters, receivers, computors, radar gear, etc. need heavy supplies to be wasted in cathode heating, plus a variety of anode voltages which can best be provided through transformer/rectifier power packs. AC supplies are ideal for this and 400 cps, enables smaller power packs to be used. But all these black boxes are generating wasteful heat and for stability must be temperature controlled. Thus still more power is needed for air conditioning and as a result, the overall efficiency of this type of equipment must be well below 10 per cent.

Transisters and other solid state devices need no heaters, and except in the power output stages, or in heavy rectifiers, run practically cold. They do not require high anode voltages, operating mostly below 24 volts DC. Where high anode voltages are needed, on such things as radar tubes, these can be produced in situ by inverter circuits of negligible weight. Telstar and other advances have proved that the frequency, power and reliability limitations of these devices are no longer significant.

We enter a new generation of electronic devices which will give the same performance at a fraction of the overall power needed for the present range.

Fuel cells promise a lightweight source of DC power for these devices and the excellent proposal to equip vehicles with AC generators and rectifiers to their batteries is another.

As stated by Major Tree, the advances in solid state power rectifiers of light weight, and high efficiency mean that any coarse AC supply, no matter what frequency, can be converted to DC where needed.

I submit that the foregoing indicates that the demand for an exotic supply in the combat zone is exaggerated and could well be met from what I term a "coarse" supply, improved to "exotic" standards only at the device that really requires it. Even our present standard generators at 50/60 cps, 415/240 volts three phase, are needlessly complicated with closer voltage and frequency regulation that is really necessary. Nevertheless, this generating standard is extremely flexible and is compatible with those of nearly every country in the world. All electrical equipment likely to be needed in the combat, or any other zone, is readily and cheaply obtainable at 50/60 cycles. On the other hand, 400 cps equipment is extremely expensive, very specialised and more complex than 50/60.

Instead of advocating this complete change of standard I suggest that MEXE should concentrate on some real power to weight improvements in 50/60 cycle equipment so that it can be more effective in the combat zone and even more useful out of it. I see nothing impractical in gearing down the output of high speed air cooled petrol or diesel engines from 3–4000 rpm to 1500/1800 rpm for operating 50 or 60 cps supplies at a very small weight penalty compared with the improved output.

I suggest that MEXE should sponsor lightweight solid state power packs which can accept a variety of "coarse" input supplies and deliver a "fine" output to the needs of GW or other complexes.

In passing, I deplore the idea of Sappers losing their air tools (although I would be delighted to see the back of the "PESCARA" compressor). There are some magnificent new rotary compressors on the market and although there have been some useful developments in heavy electric tools, they are nothing like as simple, flexible or reliable as their air driven counterparts.

However, if we must change over, let us at least be able to use the commercial 50/60 cycle product and not another range of "Military Specials" at 400 cps.

Finally, let me disabuse Major Tree of the naive belief that the introduction of this new standard would thereby end all power standardisation problems. Like Unified Threads, the result will merely be one more standard to add to those now existing.

Yours faithfully,

JOHN McDOWELL.

Memoirs

BRIGADIER GENERAL E. G. WACE, CB, DSO

EDWARD GURTH WACE, son of Major-General R. Wace, CB, of the Royal Artillery, one time Director General of Ordnance in India, was born at Poona on 19 November 1876. He was educated at Marlborough and the Royal Military Academy, Woolwich, and commissioned into the Royal Engineers on 11 January 1896.

After completing his two years' young officer training period at Chatham he was posted to India.

On 2 November 1898, whilst still a Second Lieutenant, he married Evelyn Mabel Hayward, elder daughter of Major G. Hamilton Sim, Royal Engineers, at All Saints' Church, Boileaugunge, Simla. After a short stay at Lahore he was posted to a Military Works Department appointment at Umballa but he soon returned to Lahore to join the Public Works Department and to work on the North West Railway. His railway work took him to Rawalpindi and to Allahabad where he was employed on the Fyzabad Railway Survey.

He returned home in 1903 and was posted to Chatham as Assistant Adjutant of the Service Battalion, RE, and the following year he became Adjutant of the Training Battalion, which post he held until 1907. He had played cricket for the Corps during his Young Officer days and during this his second time at Chatham he was able to renew his connexion with Corps cricket and make more runs and take more wickets.

Towards the end of 1907 he was posted to the War Office where he was specially employed in the Directorate of Fortifications and Works. During his time there he qualified as an Interpreter in German and studied for the Staff College, successfully passing into Camberley in 1910.

After graduating from the Staff College in 1912 he was posted to the Training Depot for RE Field Units at Aldershot but he was in fact specially employed under the Training Division of the War Office and responsible for organizing the reserve of civilian despatch riders, which had been formed in 1910 as part of the RE Signal Service, who provided their own motor cycles in much the same way as the old Yeomanry used to provide their own horses. On the outbreak of war in August 1914 he returned to the Training Division of the War Office and remained there until he was posted to a GHQ appointment with the Expeditionary Force in France in March 1915. After a few months in that post he became GSO II 15th Division and in May 1916 he was promoted to become GSO I 32nd Division, winning the DSO before being appointed in December of that year Deputy Director of Labour, British Armies in France with the temporary rank of Colonel. In September 1918 he was promoted temporary Brigadier-General on becoming Controller of Labour British Troops in France and Flanders. For his service in that capacity he was awarded the CB.

Brigadier- General EG Wace CB DSO

In January 1920 he was employed under the Foreign Office as British Commissioner and President of the Saar Basin Delimitation Commission. On the completion of that task in 1922 he reverted to his substantive rank of Lieut-Colonel and became CRE 2nd Division and North Aldershot, and later CRE Camps and Roads. He retired with the substantive rank of Colonel, and the honorary rank of Brigadier-General, in October 1926.

After retirement he lived in London until moving to Rye in Sussex in 1942. He later became a Freeman of that historic town. He died at his home on 1 June 1962 aged 85 years. A Memorial Service was held for him on 16 June 1962 at St Mary's, Rye. Besides his widow, his son and two daughters and grandchildren and other relations, the Service was attended by the Mayor and Corporation of Rye, the Chairman of the Rye British Legion, representatives of the Rye Salvation Army and of the Rye Dormy Club and by many friends.

MAJOR GENERAL F. G. HYLAND, CB, MC

FREDERICK GORDON HYLAND was born on 8 February 1888. He was educated at Marlborough and the Shop, and commissioned into the Corps on 23 July 1909.

Whilst at the School of Military Engineering he was an ardent Rugger player and frequently represented the Corps. He also played in the RE *v* RA Hockey Match of 1910. After completing his courses at Chatham he was posted to 30 (Fortress) Company at Plymouth. During the 1914–18 War he was closely connected with the work of the tunnellers. His first command was 171 (Tunnelling) Company, which blew the great craters for the attack on the Messines Ridge, and by July 1916 he was the Controller of Mines 1st Army; at the age of 28 he was one of the youngest Lieut-Colonels at that time serving in the Corps on the Western Front. He was awarded the Military Cross and he was five times mentioned in despatches.

After the war he spent two years at the War Office working in the DFW Directorate, and for the next two years he was employed at Chatham, firstly specially employed under the DFW and later as an Assistant Instructor in the Construction School of the SME.

In 1923 he was posted to Hong Kong where he served for three years before returning home to command 11 Field Company at Aldershot. After three years in command of the Company he became DCRE North Aldershot which appointment he held until the end of 1931; during this tour of duty he attended the Senior Officers' School.

From 1932 to 1935 he was CRE Singapore and on returning home he was given the important appointment of CRE 3rd Division at Bulford. In 1937 he became Commander of the 31st (North Midland) AA Group (TA).

In 1939 he formed 6th Anti-Aircraft Division which he commanded until the end of 1941. His Division was heavily engaged during the Battle of Britain when it directly supported the operations of 11th Fighter Group RAF by defending the heavily attacked ports and airfields in East Anglia, the Thames Estuary and the Home Counties. The Division shot down by gunfire over one hundred German aircraft during the battle. Hyland's share

Major-General FG Hyland CB MC

in this achievement was considerable; his constant personal attention to the units of his widely-dispersed command, his high professional competence and his kindly but firm character earned him the affection and respect of all who served under him. For his services throughout the Battle of Britain he was awarded the CB.

From 1942 to 1944 he was Chief of Staff and Deputy Fortress Commander, Gibraltar which at that time had great strategic importance connected with the fighting in North Africa. Before leaving the Rock he had been appointed Lieut-Governor of Jersey (designate), to take up the appointment when the Channel Islands had been liberated. Ill health, however, prevented him from filling that most fitting position and he retired on 5 April 1946.

In 1918 he married Mary Amelia, daughter of Surgeon-Major W. Jobson, who died the following year. In 1922 he married secondly Teresa Frances Nicol, daughter of G. R. Gould, Esq.

He died on 18 April 1962, aged 74 years.

W. G. R. N. pays Major-General Hyland the following tribute:—

"I went to Gibraltar as his Chief Engineer late in 1943, well after the 'Torch' landings in North Africa. I say 'his' because although General Hyland's appointment was Deputy Fortress Commander, he acted for many months as Governor and Commander-in-Chief whilst Lieut-General Sir Frank Mason MacFarlane was on his mission to the King of Italy and in the interregnum before Lieut-General Sir Ralph Eastwood became Governor.

"At that time Gibraltar was the first and last port-of-call for all aircraft from the UK to anywhere in the world and Hyland had to entertain at 'The Convent' all the notables and royalties who passed through, including our own Prime Minister on his way back from Marrakesh. The quiet confidence and tact with which he handled this distinguished and sometimes difficult brood was a bye-word. With his Tunnelling and AA background his election as Deputy Fortress Commander was a most fortunate one, but it is noteworthy that in spite of this he was most scrupulous in leaving technical matters to his subordinate. He was dearly loved by the tunnellers in whose work he took the keenest personal interest.

"He sailed when time from official duties allowed him and he raced his own Victory class boat. A truly modest man, he inspired great confidence in all who worked with him."

Sir Robert Ricketts writes:—

"I had the privilege of serving as Personal Assistant to General Hyland in Gibraltar from 1942 to 1944. He was one of the kindest and most considerate men one could possibly hope to meet. He was extremely popular with all ranks on the Rock and took naturally to the task of maintaining friendly relations with the Spanish military authorities during that difficult period."

Brigadier AP Sayer CB DSO

BRIGADIER A. P. SAYER, CB, DSO

Arthur Penrice Sayer, who died after a long illness at the Royal Victoria Hospital, Netley on 28 April 1962, aged 76 years was the eldest son of William Feetham Sayer, Esquire of Finchley. He was educated at Cholomeley School, Highgate and the RMA Woolwich, receiving his commission in the Royal Engineers on 25 July 1906. After completing his course at the SME, Chatham he went for advanced instruction at the School of Electric Lighting, Gosport.

In January 1909 he was posted to 45th (Fortress) Company RE at Gibraltar where he stayed for five years being employed on seaward defences and Upper Rock construction. On returning to the home establishment early in 1914 he was posted to 6th (Fortress) Company which manned the Weymouth and Portland defences. On the outbreak of war he was appointed Staff Officer to the Chief Engineer for Lands Front and Inland Defences.

He was later posted to command 33rd Division Signal Company at Shrewsbury and on the disbandment of that unit he was transferred to 91st Field Company. In June 1915 he went with his Company on active service to France and Belgium where he was seriously wounded and invalided home in March 1916. For his services he was mentioned in despatches and he was decorated on the field with the DSO for conspicuous gallantry near Loos on the morning of 26 September 1915. He rallied men of various units who were retiring from Hill 70, and it was largely due to his cool action at a critical moment that the troops in the locality were able to hold their ground. Later he rendered great services in collecting stragglers to hold captured German trenches, and continued doing this until he was overcome by gas.

After discharge from hospital he was posted for light duty to the RE Training Depot at Aldershot for six months before being sent to the Royal Military Academy, Woolwich as an Instructor and Company Commander. He spent in all over four years at the Shop. During his time there he married Blanch Mary, widow of Captain David Scott Dodgson and youngest daughter of Dr J. W. Leacroft of Derby, at St Lukes, Redcliffe Square, London on 21 December 1916.

He embarked for India during the second half of the 1921 Trooping Season. After a short stay as Staff Officer to the CRE North West Frontier Province, Peshawer he was made CRE (Works) of the Independent Brigade Area at Allahabad. In May 1925 he was appointed CRE, RAF Headquarters at Simla and Delhi where he was placed in charge of all RAF works including the development of the Salmond Scheme and the construction of the airship base terminal for the ill-fated R101. He also carried out reconnaissances for landing grounds at Chitral and for opening air routes between Quetta and Bangalore and between Peshawer and Calcutta.

On reverting to the Home Establishment in 1926 he spent almost three years as Staff Officer to the Chief Engineer Eastern Command at the Horse Guards. In January 1929 he took over command of 11th Field Company at Aldershot and remained in command of the unit until becoming a Lieut-Colonel in September 1930.

On promotion he was appointed Vice-President of the RE Board, and in that capacity he carried out special reconnaissances for the Air Defence of Gibraltar and Malta in 1932 and Hong Kong, Singapore and Aden the following year. For his outstanding work in this connexion he was made a Brevet Colonel. In March 1934 he was loaned to the Air Ministry for special duties investigating and selecting underground storage sites for bombs and ammunition. In October of that year he was posted as an Assistant Director of Works in QMG 9, the War Office for technical engineer works and personnel and liaison duties with the Air Ministry. In 1937 he was made President of the RE and Signals Board when particular stress was being placed on the development of radar. The Board was subsequently transferred to the Ministry of Supply and divided into three separate organizations, Sayer remaining in charge of radar and air defence until he was placed on the Retired List in November 1940. He was, however, re-employed forthwith as Deputy to DAA & CD, the War Office for radar work. He subsequently became Director of Radar with the duties of developing new equipments and assessing the possibilities of the results of research for improving Army Radar. In January 1945 he again reverted to the Retired List and he was awarded the CB for his outstanding services. He continued to be employed in a retired capacity from June 1945 to compile the official Historical Monograph on "Army Radar", a task which took just over three years to complete. He was also a frequent contributor to the *Royal Engineers Journal*.

After his retirement he was for some years Chairman of the Bexhill and District Branch of the Royal Engineers Association. He was keenly interested in the work of St Mark's Church, Little Common which he represented on the Ruri Decanal Council besides being a member of the Diocesan Council, and he took an active part in many local welfare and charitable works.

Among the mourners at the service in the Royal Chapel of the Royal Victoria Hospital were his widow, Vice Admiral Sir Guy Sayer and Lady Sayer (brother and sister-in-law), Rear Admiral Sir Lionel Sturdee and Lady Sturdee and Mr and Mrs S. A. Phillips (brothers-in-law and sisters) and representatives of St John and British Red Cross Welfare Services.

NAMS pays him the following tribute:

"I had not met Sayer until I joined QMG 9 as a Staff Captain. He was outwardly an austere man in many ways but was eminently reasonable and approachable. When you submitted a technical matter to him you had to be sure of your facts and arguments for he was very quick to pick out the weak spots and probe them. Once you had convinced him, you could be sure of his support.

If anything went wrong he always accepted the blame and never suggested to others that his staff had failed him. He inspired loyalty and I have never served under a better officer.

He did not suffer mistakes gladly and was, at times, impatient of others whether they were senior to him or not. But he was far sighted in outlook and subsequent events often proved the rightness of his opinions.

I saw him many times during the long period of his final illness. He was still a fine looking man and inspired respect and devotion in the staff who nursed him."

CAPTAIN (RIDING MASTER) A. L. ALLAN

CAPTAIN A. L. ALLAN, the last RE Riding Master, died on 29 March 1962 aged 85 years.

He was commissioned as Lieutenant and Riding Master on 25 September, 1914 and he retired in 1922. His predecessor was Major J. E. Griss, who had been commissioned Riding Master from the Gunners in September 1894, and who became DAD Remounts at Aldershot on the outbreak of the 1914/18 War. Griss himself succeeded a Captain and Riding Master D. Gillon who had held that post since 1875. For almost fifty years these three officers had been responsible for equitation training in the Corps. To Allan, however, fell the enormous task of passing through Riding School a countless number of RE officers and Mounted Sappers and Drivers during the First World War.

A previous Officer Commanding the RE Mounted Depot at Aldershot writes: "Allan was a quiet, capable man who had great patience with the young horse and the young recruit. He was well liked and respected by all ranks. His name was well remembered in the RE Mounted Depot when I took over command in 1928. However, by that time Riding Masters and Riding Courses had given way to Weedon-trained Equitation officers and Equitation Courses."

N.A.C.R. writes:

"I did a Mounted Duties Course under Allan in 1915 and served with him in the RE Mounted Depot in 1920.

"A riding course with Allan taught us a lot and was enjoyable. He was always ready to help and encourage a young officer or NCO who showed interest in any branch of equitation. It was due to his training that the first Sapper NCO to go to Weedon did so well there and brought such credit to the Corps."

Book Reviews

PROGRESS IN AERONAUTICAL SCIENCES

Volume II—Boundary Layer Problems

(Published by the Pergamon Press. Price 90s)

This second Volume of the series of the Progress of Aeronautical Sciences contains two papers, the first on Turbulent Boundary Layers in Incompressible Flow by J. C. Rotta of Aerodynamische Versuchsanstalt, Göttingen, and the second on Boundary Layers in Three Dimensions by J. C. Cooke and M. G. Hall of the Aerodynamics Department, the Royal Aircraft Establishment, Farnborough. The Volume has been edited by Antonio Ferri, Professor of Aerodynamics, Polytechnic Institute of Brooklyn, USA, D. Küchemann, of the Royal Aircraft Establishment, Farnborough, and L. H. G. Sterne of the Belgian Training Centre for Experimental Aerodynamics. Both papers are very substantial and mathematically highly technical. They do, however, set out the most up-to-date thoughts on the problems discussed and they are presented by internationally famous experts in this field of knowledge.

"GREAT ENGINEERS"

By L. T. C. Rolt

(G. Bell & Sons Ltd, York House, Portugal Street, London, WC2. Price 18*s* 6*d*)

The author of this book has already produced works on such famous men as Brunel, Telford and George and Robert Stephenson. In the Preface to his latest book he explains that his purpose was to tell the story of the Industrial Revolution in England—by far the most significant the world has ever known—through the lives of ten engineers.

The ten he has selected range from Abraham Darby, born in 1678, the iron master and discoverer of the art of coke smelting, to Doctor Frederick Lanchester. who died in 1946, the automobile engineer and a pioneer in the science of aeronautics, The others, in order of appearance in the book are Thomas Newcomen, the pioneer of steam power, William Jessop, builder of canals and railways, Matthew Murray, pioneer mechanical engineer, Henry Maudslay, master mechanic, Joseph Locke, railway engineer, John Fowler, pioneer of mechanical agriculture, Benjamin Baker, designer of the Forth Bridge and R. E. Crompton, pioneer electrical engineer who when serving in India as an Ensign in the Rifle Brigade, persuaded the C-in-C and also the Viceroy to allow him to experiment with steam road engines as a substitute for bullock-drawn military transport.

The story of each man's life makes fascinating reading; their triumphs, failures and the commercial skullduggeries of their day are all described and in a most absorbing way. The author has certainly achieved his aim of describing the technological advances of the Industrial Revolution brought about by these great engineers and men of vision. It is a book every Sapper officer should read. J.L.

ADVANCED MATERIALS

By C. Z. Carroll-Porczynski

(Published by Astex Publishing Co, Ltd, Guildford. Price £2 18*s* 6*d*)

The author has gathered together, in one slim volume, the previously scattered information on the characteristics of the new materials that have been developed during the past decade to meet the structural forces and thermal conditions experienced by high-speed flight through the atmosphere and outer space.

The information, photographs and technical data, were obtained from the leading laboratories, research societies, universities and manufacturers of the UK and USA, who specialize in the development of refractory fibres in combination with heat resistant resins, or fibre-reinforced ceramics or metals. All the materials reviewed in this book are relatively new. Some of the materials are of academic interest only, others have reached the preliminary development stage, many are in regular production. Although developed primarily for aerospace industry the materials are finding application in other branches of industry where considerations of weight and cost are important.

The eleven chapters of the book cover a wide range, from a summary of high temperature problems to the sources, properties, manufacture and uses of fused silica fibres, those of high silica content ("Refrasit"), aluminium silicate ("Fiberfrax"), potassium titanate ("Tipersul") and refractory oxide fibres. In addition considerable data is given on the use of asbestos in high temperature resisting "composite" materials and their development for aircraft and missiles. The production and use of metal wools, the use of metal-coated glass yarns with their resistance to abrasion and flexing, and the progress made in the development of the completely non-inflammable organic material known as "Pluton", are all adequately covered.

The text is printed on good quality paper and is easy to read. Each chapter is well illustrated with photographs and diagrams, and also include comprehensive lists of references and further reading.

There is sufficient simple, factual information in the book to give the layman a good insight into the realm of advanced materials without heavy study. At the same time the reviews of recent investigations and important patents are worthy of those readers who already have a good knowledge of the subject.

For the military engineer the power/weight ratio is one of paramount importance in the field, and perhaps the future use of some of these materials may be the answer to many of the problems where weight and cost have to be considered. F.T.S.

LADIES IN THE SUN—THE MEMSAHIBS' INDIA, 1790–1860

Edited by J. K. Stanford

(Published by The Galley Press Ltd, Aldine House, Bedford Street, London Price 25*s*)

This is a most readable book compiled from extracts from diaries and letters written during the century leading up to the Indian Mutiny, describing long, hazardous and generally only one way voyages around the Cape in East Indiamen and conditions in the service of the Honourable East India Company in those distant days when the white man's burden in India was a heavy and unpredictable one, and life was often a race against death from disease, pestilence or famine, or indeed in some terrible massacre or disaster.

The book perhaps slightly over-emphasizes the sordid and unethical behaviour of some of John Company's more senior officials and the obfuscated bacchanalia of the Nabobs' lives—a popular tendency in these modern anti-colonialism days. The book, however, does pay tribute to the vast number of memsahibs who brought into the world and stoically reared large families under conditions which today would seem appallingly impossible, and a passing reference is made to the dedicated women of the missionary societies who devoted their whole lives to improving the lot of the women of India and with whom there was no such thing as apartheid. J.L.

THE WAR AGAINST JAPAN—VOL III

By Major-General S. Woodburn Kirby, cib, cmg, cie, obe, mc

(Published by HM Stationery Office, 1961. Price 63*s*)

Vol I and Vol II of the *History of the War against Japan* were sombre accounts of the initial reverses which overtook Great Britain in the Far East and left her armed forces hard pressed to defend even the gates of India. In the period covered by this volume, however, the tide of events at last began to run strongly in her favour. The Japanese reacted to the changing circumstances in characteristic fashion. They decided to anticipate the expected British offensive in Burma by attacking themselves. The élan, ferocity and self-sacrifice of their devoted soldiery were to off-set the comparative dearth of logistic resources, which their ambitious operations required. Within a month of the Japanese decision being taken, the famous "battles of the boxes" began, first of all in Arakan and then at Imphal and Kohima. After some hair-raising crises, they were duly won by the Fourteenth Army commanded by Lieut.-General W. J. Slim, who is now very properly a Field-Marshal and a Viscount.

Curiously enough these most important battles, which settled the fate of the Japanese in Burma, happened almost of their own volition, unprompted by any specific directive calling for the destruction of the Japanese Armies. The British conduct of the war in Burma was, in fact, bedevilled by the so-called "global strategy" of the US Chiefs of Staff. To them Burma was a theatre, where the British were fighting extremely badly and which was only important as a stepping stone to the US stategic airfields in SE China. Long after the brilliant American operations by air, sea and land in the Pacific had made it probable that Japan could be defeated without bombing attacks from the mainland of Asia, the China myth continued to exercise a baleful influence on events in Burma.

Thus the emphasis in the long delayed directive to Lord Mountbatten for the 1944 campaign lay on the road, the pipelines and the air lift of thousands of tons of war material to China. Nor was this prodigious administrative task made any easier by being in the hands of the American General Stilwell, known far and wide as "Vinegar Joe". From the pages of this book Stilwell emerges as a most difficult and cantankerous commander and hardly the man to fill with success the several arduous roles, which, for one reason or another, fell to him to play. No doubt he had great qualities but working in well with his British Allies was not one of them.

Years ago in World War I a blasphemous version of the Athanasian creed made mock of the high command set up on the banks of the Nile. But the complications, which disturbed Cairo in 1917 were but child's play compared to those which confronted SE Asia Command at Delhi in the late autumn of 1943. There, the energetic and determined Lord Mountbatten had to sort out, as best he could, the often conflicting views of the President and the US Chiefs of Staff on the one hand and of the Prime Minister and the British Chiefs of Staff on the other—not to mention those of Stilwell and Generalissimo Chiang Kai-shek. The planning vortex for the Burma theatre included no less than twelve major operations, each with a code name, of which only five were ever carried out. That under such planning pressure, the Staff at SE Asia Command became gigantic is not surprising. How vast it became is not disclosed in any appendix, which, historically speaking, seems to be a regrettable omission. Similarly the appendices omit reference to the Eleventh Army Group and the Fourteenth Army both of whose staffs were presumably of importance.

Also at Delhi the devoted Auchinleck, as C-in-C in India, was applying a lifetime's knowledge of Indian military affairs to supplying the requirements of the British, Indian and African formations, which were shortly to be engaged in a life and death struggle on the Burma border.

For his part, Lord Wavell, the Viceroy, was wrestling with grave political unrest all over India and the onset of famine in Bengal. He also held a watching brief from the Cabinet to ensure the "harmonious co-operation" of Mountbatten and Auchinleck. In short the military scene in the autumn of 1943 was pretty murky and the military machine definitely over-complicated. But the men now in charge of affairs were all of them experienced military leaders, who were determined between them to master the situation and to make everything work.

General Slim had obviously thought much on the tactical and strategical problems presented in the handling of seven or eight divisions on a four-hundred front of jungle. Hence his call for "tough infantry and air transport" which in turn presupposes "all round defence and air superiority". The soft spots on such a frontage are bound to be numerous. On one occasion in Arakan, a Japanese commander marched 5,000 men at night in a close column 16 men abreast right through the British line to a village 15 miles behind the front. Earlier in the war this tactic might have succeeded but it failed against Slim's well-trained troops in "box defences". But it was fortunate for the Fourteenth Army that the timing of the Japanese offensive went adrift when the attack in Arakan failed before that at Imphal–Kohima had developed. Thus Slim was able to reinforce his hard pressed centre by air with experienced Divisions from Arakan.

Without doubt "the tough infantry and air transport" concept has a future in many kinds of war, particularly for a coup de main or on a long front lightly held.

On the vexed question of Wingate and his six LRP Brigades, one of Major-General Kirby's final comments is that the results achieved were not commensurate with the resources which they consumed. This judgement is absolutely true and will be that of history. Wingate had, nevertheless, a touch of genius about him and he tweaked the noses of the Japanese in Burma just at a time when it badly wanted doing. But tweaking noses is one thing and winning wars is another.

The reader will find the going pretty heavy as "he plunges about in the jungles of Burma"* following the history of the war. He will usually have three maps in

* WSC.

action with a sketch thrown in for good measure. Yet the story seems very accurate and the elusive place-names appear in the end to be all present and correct. Wingate's "24th Parallel", of which he made a great feature, could be shewn with advantage on Map 15. B.T.W.

SINGAPORE—THE JAPANESE VERSION

By COLONEL MASANOBU TSUJI, LATE GENERAL STAFF, JAPANESE ARMY

(Published by Messrs Constable & Co London. Price 30*s*)

Soon after the abrogation of the Anglo-Japanese alliance in 1921 at the behest of the U.S.A., Singapore became a word of fear to successive British Governments. Their anxieties stemmed from the knowledge that, in the event of a war with Japan, the successful defence of our Far East bases would entirely depend on the establishment of British or Allied maritime supremacy in the China Seas. If, as seemed probable, Western seapower there were to be inadequate, Hong Kong would at once be indefensible and Malaya would quite possibly become the object of a seaborne Japanese invasion.

Between the wars, this disturbing and unfamiliar situation was generally recognized in British military circles and it is believed that various Staff exercises explored the problem in some detail in an attempt to discover how long Malaya could be expected to hold out without relief. Such studies are useful on the logistics but not so good on the imponderables of war. Even in regard to logistics, however, the conclusions about Malaya tended to overstress the jungle terrain of the peninsula and apparently missed the significance of the fishbone pattern of excellent feeder roads and the railway, which ran along the whole length of the West coast. According to this book, the Japanese captured several thousand motor cars and trucks together with over a thousand locomotives and railcars, so that plunging about in the jungle was evidently only necessary during battles. The import of the road fishbone was certainly not lost on the Japanese, who cracked along it with every vehicle, which they could lay hands on, from bicycles and cars to some invaluable tanks. Incidentally the Empire forces in Malaya had no tanks, may be because of the "jungle theory".

On the above evidence, some of which is only hearsay, the estimate of the resistance potential of the Malay Garrison was probably much too optimistic and couched in months rather than weeks. In the event, only 71 days separated the landing at Singora from the capitulation at Singapore, which lies 1,100 kilometres away to the south. As Colonel Tsuji justly points out, this is probably a record in the long annals of war. Manifestly some cause, other than a mere disregard of roads and a railway, must explain such an astonishing performance. It was, of course, an imponderable and lay in the great difference in the fighting experience of the troops engaged. The Japanese generals and their soldiery had been at war for ten years in China. Combine this long apprenticeship with the ethics of a warrior race, which had hardly known defeat for over 2,000 years, and the result is formidable.

Inexperience of war has to be offset by inspired leadership and fierce training. Unfortunately neither of these essentials were to sustain the Empire troops in Malaya. Warfare against Japan had hardly received a thought and for some extraordinary reason the fine quality of the Japanese Army, although fully reported by most competent military attaches, had been played down. Our leaders in Malaya were good average commanders but, be it said humbly and without presumption, they were not the men to animate the defence in an ordeal, which rather resembled that of the Russians at Port Arthur in 1904. No wonder that the unfortunate British, Australian and Indian soldiers concerned seemed to the Japanese to fight "without sincerity", as the author puts it.

Another potent cause of the Singapore debacle was saddling the RAF with the sole responsibility for destroying any attempted Japanese invasion. The outcome of such a plan would have been problematical in the best of circumstances. As it fell out, the aircraft required to make success even conceivable never reached Malaya and the Japanese landings suffered only trifling damage from the air. Unfortunately, however, the dispositions of the RAF and the Army ran counter to each other and a fatal dispersion of Army formations was the result. Colonel Tsuji himself expresses surprise at finding such a large proportion of the Empire formations hundreds of miles to the north of the fortress, the defence of which was the supreme object. Possibly a plan of defence more closely centred on Singapore would have enabled the garrison to make a more prolonged resistance. The writer of the Japanese version of Singapore writes passionately and well in the naive heroic idiom of his race. The book is not long and is well worth reading by those who do not shun a close up study of one of the worst defeats in British military history. B.T.W.

Technical Notes

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada* for March 1962

PLANNING AVALANCHE DEFENCE: The Trans-Canada Highway is exposed to the danger of avalanches where it traverses Rogers Pass, British Columbia. This paper describes the investigations carried out, and the protective works proposed, in order to reduce interference with the highway. Various causes of avalanches are classified, and methods of defence are summarized.

It is interesting that, where ground conditions permit, earth mounds 15 to 25 ft high, built in two or more rows and staggered, are a most effective, as well as the most economical, form of braking device. The use of catching and diverting dams, the provision of snowsheds, and temporary measures such as the firing of explosive charges, or artillery fire, are also discussed.

THE BEECHWOOD FISH HOIST: The importance of preserving natural salmon spawning areas in the rivers of Canada is fully appreciated by hydro-electric engineers, and the problems involved were clearly expounded in the October 1961 issue of *The Engineering Journal* (see *RE Journal*, March 1962). The Beechwood installation on the St John River, New Brunswick, provides an elevator fish hoist instead of the more usual fish ladder. Descriptions of the general fishway facilities and of hoist operation are interesting, and are unusually well illustrated. Modifications incorporated as a result of practical experience, and others which are contemplated, are also summarized.

THERMAL WEDGE EFFECT IN HYDRODYNAMIC LUBRICATION: This mathematical investigation exemplifies the practical effect of initial assumptions, and the difficulty of correlating theoretical and experimental conclusions.

A RESEARCH VIEWPOINT ON ENGINEERING EDUCATION: This short paper stresses the growing importance of engineering research, and suggests that one of the main functions of a university is to produce graduates with the capacity for original thought.

RECENT DEVELOPMENT IN AUTOMATIC ELECTRODE BOILERS: After discussing the essential electrical characteristics, the author describes a high-voltage electric boiler designed to utilize off-peak hydro-electric power.

Notes from *The Engineering Journal of Canada*, April 1962

GEOLOGY OF THE SOUTH SASKATCHEWAN RIVER PROJECT: This is a description of the unusual geological conditions which have complicated site selection and design for the South Saskatchewan River hydro-electric power and irrigation project. The practical effects on engineering work are not discussed.

DESIGN CONSIDERATIONS FOR LARGE RADIO TELESCOPES: Space research depends largely upon the use of radio telescopes, and this paper should help the uninitiated to appreciate both their value and their cost.

POWER STATION FEED HEATERS: This is a technical survey of the feed heater requirements in modern plant, and of some of the design and construction problems involved. The mechanical engineer will find some useful practical information.

UNIQUE DESIGN IN GLULAM: Glulam is a glued laminated material, which was found very suitable for the construction of the main framework of large storage structures of most unusual design. Each of these can hold 37,000 tons of potash, the stockpile comprising an underground cylinder 16 ft deep and 204 ft in diameter, surmounted by a cone of material 62 ft high. The above-ground structure is in the form of a truncated cone, topped by a head house for conveyor equipment and galleries. After a brief exposition of the initial design, the author gives an interesting description of comprehensive tests carried out on a scale model, to obviate cumbersome mathematical analysis of many different loading conditions. The manufacture and erection of the actual prefabricated structures are briefly described. This is an admirable account of an original conception, leading to an eminently practical and economical installation.

SOME ENGINEERING APPLICATIONS OF ANALOG COMPUTERS: Computers are being used increasingly for the solution of engineering problems. This analysis goes a stage further than previous papers on the subject, and is more practical than most.

Notes from *The Engineering Journal of Canada*, May 1962

ENGINEERING REVIEW, 1961: This annual feature is presented in 14 very brief summaries of achievements and trends in different industries. The general picture is one of slight improvement over the exceptionally difficult previous year. The future seems to call for determined effort rather than for rosy spectacles.

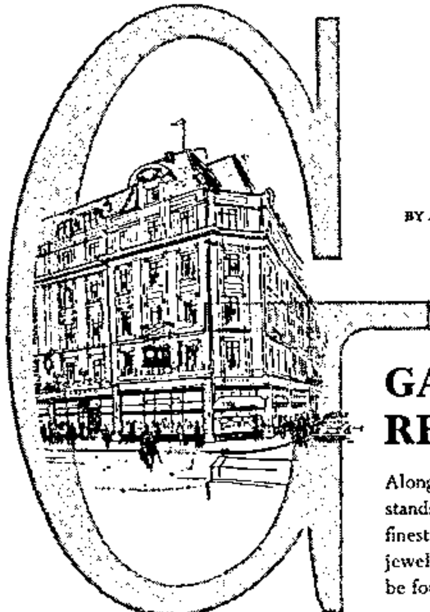
LIMIT DESIGN OF R.C. CONTINUOUS BEAMS: The plastic design theory for steel structures has both devotees and critics. This paper presents an inelastic design method applicable to continuous beams, and achieves solutions in graphical form. It offers a considerable mathematical exercise without recourse to calculus.

CIVIL ENGINEERING EDUCATION: This is an authoritative addition to the lengthening series of papers on a controversial subject. The author concedes that the profession needs both the G.P. and the specialist, and emphasizes the importance of being able to apply knowledge of science and mathematics, and of the capacity for constructive thought.

UNUSUAL LOG DRIVING PROBLEM: Hydraulic problems are often best solved by the use of scale models. Unfortunately part of this paper, including two illustrations, has been omitted by the printer, but the model technique appears to have shown the way to a practical solution.

The other two papers in this issue are not of particular interest to RE officers, but those interested in "glulam" (see Note from the April issue) may care to refer to pages 65 and 66.

R.P.A.D.L.



A recent silver statuette created by Garrard in exact detail from life.