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DECEMBER, 1968

Paper for Presentation to a Joint Meeting of
The Institution of Royal Engineers and
The Institution of Electrical Engineers

Entitled

"Electrical Power for the Army in the Field"

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AND

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SECTION 1—THE ROLE OF THE ROYAL ENGINEERS

THERE is widespread misunderstanding of the role of the Royal Engineers in connexion with the generation and distribution of electrical power to Service users. This section of the paper, therefore, deals firstly with the division of responsibility between the Ministry of Public Building and Works (MPBW) on the one hand, and the Ministry of Defence on the other, and then explains how such responsibilities are shared between Arms of the Service.

The MPBW is responsible for the selection, installation and maintenance of all electricity supply equipment in garrison areas in peace and war for all three Services. In operations in areas where MPBW "cannot move freely nor exercise their normal technical and managerial control" the responsibility for the generation and distribution of electrical power on land rests with the Royal Engineers, subject to the special Corps responsibilities set out below. The Royal Engineers may, therefore, be regarded as the "military electrical supply authority" in the field.

Within the Ministry of Defence, the staff sponsorship of electrical generators (excluding those mounted in vehicles) is shared between the Royal Engineers and Royal Signals staffs on the following basis. The Royal Engineers sponsor all 400 Hz generators, all three-phase 50 Hz generators and single-phase 50 Hz generators over 10 kVA output—the Military Engineering Experimental Establishment (MEXE) at Christchurch being the establishment responsible for research, development and testing of such equipment. The Royal Signals sponsor single phase 50 Hz generators of 10 kVA output or less—such equipment being developed by the Signal Research and Development Establishment (SRDE), which is also located at Christchurch. The Fighting Vehicle Research and Development Establishment (FVRDE) at Chobham is responsible for the development of generators mounted on vehicles.

With regard to the provisioning, holding and repair of electrical generators the division of responsibilities between Corps is on a different basis. The Royal Engineers provision, hold and repair all generators over 62·5 kVA (50 kW at 0·8 pf) output, reserve stocks of generating sets and ancillary equipment being held at the

Central Engineer Park at Long Marston in Warwickshire. The Royal Army Ordnance Corps (RAOC) provision and hold all generators of the above output and below and the Royal Electrical and Mechanical Engineers (REME) repair all generators within this category. REME's functions have been fully explained in the paper "The Army and Electrical Engineering—REME's Vital Defence Role" by Colonel J. Harris, which was published in the proceedings of the Electronics and Power Division of the Institution of Electrical Engineers in April 1965.

This paper has been written to show how the Royal Engineers have met their responsibilities in this particular field in the post-war years, how they are at present trained and equipped, and how they are preparing to meet their future commitments. It also includes a section dealing with current developments of related equipment at MEXE.

SECTION 2—RETROSPECT

It would be inappropriate in a paper of this nature to devote too much space to a description of past projects, but in view of the vital part played by members of the Institution of Electrical Engineers, who served in the Royal Engineers either during the war or subsequently during their National Service, a brief recapitulation of a limited number of such projects has been included. This may raise nostalgic memories and at the same time serve as a background to the discussion of our current role and problems.

A. *Operations of 21 Army Group in NW Europe 1944/45*

In an early stage of the operations it became clear that an organization was required to repair and operate large power stations for military purposes in the Rear Maintenance Area. A special unit, 163 CRE (Power), was formed under Lieut-Colonel (now Colonel Sir Norman) Elliott. Its first task was to rehabilitate Caen power station, which had suffered extensive bomb damage. This station comprised four water tube boilers (450 psi at 425°C) and four turbo-alternators, generating at 2,800 volts 3 phase 50 Hz, of which two were modern units rated at 16 MW, one older unit rated at 6 MW, and one old veteran standby unit, which was virtually obsolete. Work was concentrated on putting into operation the 6 MW set, which was least damaged, together with one boiler and this was ready for a trial run six weeks after the clearance of debris had begun. It is interesting to note that in this heavily blitzed area, where the distribution network was in places almost untraceable, more man-hours were needed to restore the distribution system than to repair the power station, and at every stage more power was available than could be utilized. In early October the station was successfully recommissioned, although severe troubles were experienced when an attempt was made to parallel the turbo-alternator with the 275 kW rail mounted diesel sets, which had been brought in to provide emergency power for the dock cranes. By mid-November the first of the 16 MW sets had been recommissioned, the 30 kV lines to Bayeux were on load, and it was possible to hand over the station to the local civilians and move the military staff to Antwerp. During the winter 44/45 the power stations at Schell and Merxen in the Antwerp area were repaired and recommissioned, and a power line was built from Merxen to Roosendaal to feed power into the Dutch HT grid. In addition two oil-fuelled ship-mounted power stations of 28 MW capacity were brought over from the USA to boost the local power supply. These were installed at Antwerp and Ghent during February 1945 and made a significant contribution to the fuel position in Belgium and Holland. During the campaign the Royal Engineers installed or recommissioned over 400 generators, erected 280 miles of overhead transmission line, and laid over 3,000 miles of distribution cable. It appears unlikely that work of this scale and magnitude will be undertaken by the British Army in the future—but the lessons remain valid—the need for a thorough understanding of the basic principles of electrical and mechanical engineering, the ability to improvise, and the importance of close understanding between supervisory and technician grades.

B. *Electrical Installations in Christmas Island*

The base at Christmas Island was established to support Force GRAPPLE in connexion with the British H-bomb tests in the Pacific, during the period 1957–60. As scientific and base facilities built up, so the requirement for power and light increased greatly. In the test area alone, nearly a hundred small generating stations had to be set up and operated at different localities. In rear areas, the number of separate power stations was reduced by rationalization, to economize in manpower and running costs, and a power station comprising eight 300 kW sets was built at the main camp. At the main airfield an underground high tension ring was installed. The high rate of corrosion resulting from the salty atmosphere involved a heavy maintenance commitment on electrical distribution lines. In order to keep resultant interference with user supplies to a minimum, it was important to sectionalize circuits to permit local isolation of faulty areas. Stand-by sets were provided at vital points to serve the operating theatre, the airfield control tower and laboratories which required continuous operation.

The installed capacity for the base finally amounted to around 4,200 kW, including the airfield, port and communication centre. The sets included the eight 300 kW skid mounted units, ten 120 kW units, five 50 kW units and ten 25 kW units—all generating at 415/240 volts, 3 phase, 50/60 Hz—in addition there were a number of smaller sets for particular tasks. The larger sets were concentrated in three power stations at the Main Camp, Airfield and the Joint Operations' Centre. The distribution system comprised some seven miles of overhead 6·6 kV line plus the 4 mile 3·3 kV underground ring at the main airfield. Owing to the shortage of ·225 sq in stranded copper wire, use was made of salvaged US Army solid drawn copper for spurs from the ring main and this proved satisfactory. For distribution to tents, the Enfield catenary system was used. Groups of four tents were spanned with this equipment—each pair of tent being fed from a light alloy junction box with 40/0·0076 VIR conductor.

This project was of particular interest, because the location was in an area where no local technical resources were available. In view of the limitations on transport facilities, planning had to be meticulously accurate. Stores and spare parts had to be reduced to a minimum and personnel trained to ensure speedy and accurate installation coupled with efficient operation. Above all, this project served to enhance the close-co-operation between the Royal Engineers and the Royal Air Force.

C. *Military Power Station at Dharan, Nepal*

This station was built to supply electrical power to a new Cantonment occupied by the British Gurkha depot in West Nepal, where no local electricity supply was previously available. The station was designed by the Royal Engineers in 57/58 and commissioned in August 1960. It was manned by Indian and local labour under military supervision and in 1964 was taken over by the Ministry of Public Building and Works, under whose control it continues to operate. The local climatic conditions are severe, with a maximum summer temperature of 107°F and a relative humidity of 99 per cent. The station comprised four turbo-charged diesel engines (rated at 520 bhp under local conditions) directly coupled to alternators rated at 300 kW at 0·8 pf running at 600 rpm, and generating at 415 V, 3 phase, 50 Hz. The main supply is taken direct to four 300 kVA transformers, where the voltage is stepped up to 11 kV and fed into the HV distribution system comprising underground paper insulated armoured cables. A substantial reserve fuel supply was essential in view of the remoteness of the site and three 50,000 litre tanks were erected to give a total capacity of 2,600 tons. These are replenished by Burma Shell from their depot in India 45 miles away. The main loads are of a domestic nature—cooking, water-heating, air-conditioning and refrigeration. Power is also required for the hospital and the ice plant. The usual hazards of a tropical site are encountered—lizards in the bus-bar chambers, insects (by the barrow load) on radiator grills and engine air intakes, and snakes in the cable ducts. For a power station in such a remote area, where spare parts may take up to eighteen months to arrive, this station has a remarkable record. During its eight years of operation there has been no disruption of supply apart from planned maintenance operations. Its successful operation has enabled the personnel of this isolated depot to enjoy the benefits of civilization to an extent previously undreamed of in this part of the world.

D. *The Malacca Cantonment—Malaya*

After the granting of independence to Malaya in 1957, it was decided to build a new cantonment for the Commonwealth Brigade and site construction began in mid-1958. The electrical project involved the construction of a main 11 kV switching station and eighteen sub-stations, including the erection of all the requisite switch gear and transformers, the installation of earthing and protective devices and overhead and underground distribution lines. The work was carried out by civilian contractors from Singapore under the direct supervision of RE staff at a cost of 830,000 dollars. Permanent projects of this type, using civilian contract labour, will in the future come under the control of the MPBW, but it has been included to show the ability of the RE staffs to cope with this type of contract should the need arise.

E. *Hamala Camp—Bahrein*

This project is typical of the small tasks, which the Royal Engineers may be called upon to carry out at short notice. The aim was to provide emergency accommodation for British troops in a virgin desert site in five months. The main electrical load was that of the air-conditioning units in the forty-two Twynham huts in the camp and in addition a 10-ton cold store and numerous small domestic refrigerators. The electrical project involved the erection of 1½ miles of 11 kV overhead line, the installation of four 500 kVA transformer sub-stations linked together with underground HV cable, the distribution network to the camp, and the installation of a transportable 300 kW generator to take the peak camp load. In the event, this work was completed within the stipulated five months. The electrical installations were constructed under RE supervision making the maximum use of British troop labour.

F. *Operation CROWN—North East Thailand*

The most recent electrical project worthy of mention, is that in connexion with the building of a strategic SEATO airfield in north-east Thailand. The main project "Operation CROWN" was begun in January 1964 and completed in December 1966. It involved the construction of a concrete airstrip with parking and dispersal areas and full airfield ancillaries. The power station comprised three 120 kW sets generating at 415 volts, 3-phase, 50 Hz. Distribution was by overhead line on tubular metal posts. The main load was of a domestic nature to meet the requirement of a 650-man camp and included air-conditioning, fans, water heating and cooking. There was also a small "industrial" load in connexion with the airfield workshops and service areas.

G. *Gibraltar*

This retrospect would be incomplete without mention of the electrical installations in Gibraltar. This station holds a special place in the history of the Royal Engineers, since it was here in 1772 that the first Company of Military Artificers was raised to assist in the defence of the fortress before the Great Siege. Calpé Hole Power Station was planned and erected by the Royal Engineers. It is located in a rock chamber some 300 ft above sea-level. It was first commissioned in 1955. The station comprises three 6 cylinder, opposed piston, 2-stroke CI engines, developing 1,470 bhp at 300 rpm coupled to alternators rated at 1,290 kVA, 6,000 V, 3-phase, 50 Hz. These fine old engines have done yeoman service, but have now reached the stage of obsolescence and will shortly be placed on a care and maintenance basis to meet emergency peak loads. In 1956 a fourth set was added to the station. This was a gas turbine set developing 1,225 bhp at 1,500 rpm coupled to an alternator rated at 1,250 kVA, 6,000 V, 3-phase, 50 Hz. This set has run satisfactorily in parallel with the diesel sets, although extreme care was necessary in the synchronizing operation. Cooling water was supplied from two overhead tanks each of 7,000 gallons capacity, whence it passed by gravity to the engines and thence to a hot well from which it was circulated through massive fan-cooled radiators back to the overhead tanks. Distribution was by means of a 6·6 kV underground ring main to a number of sub-stations. This station is currently operated by personnel of the Fortress Squadron RE on behalf of the Royal Navy. In addition to the main power station, a subsidiary power station was erected at Windmill Hill in 1959 and operated until 1966 to provide additional power during the reconstruction of the RN Dockyard power station. This temporary station comprised six of our standard transportable 300 kW sets, feeding through individual 300 kVA transformers—the HV sides of the transformers being paralleled and connected into the 6·6 kV ring main. With the closure of Calpé Hole power station, all service loads will in future be taken by the reconstructed RN Dockyard station—but arrangements have been made for some RE operating and maintenance personnel to be incorporated into the manning programme of this station—thus preserving the traditional RE responsibility for electrical supply on "The Rock".

SECTION 3—TRAINING OF ELECTRICAL SPECIALISTS AND TRADESMEN

In common with any large civilian organization the Royal Engineers have a responsibility for recruiting and training personnel in requisite specialist skills. To meet our electrical engineering commitments, we train personnel in three main categories, broadly equivalent to the basic civilian categories of supervising engineer, technician and tradesman. These military categories are:

(*a*) *Officers*

Either Regular Officers trained on specialist courses or Quartermasters (Electrical and Mechanical Officers) promoted from the technician grade of Clerk of Works.

(*b*) *Military Clerks of Works* (*Electrical*)

This is a military technician grade, and is recruited from military tradesmen. Clerks of Works hold the ranks of Warrant Officer or Staff Sergeant.

(*c*) *Other Ranks*

The only relevant trade is Electrician RE and men are sub-divided into three qualification ratings—Class III (Improver), Class II (Journeyman) and Class I (Master-Tradesman/Supervisor). They may hold any rank from Sapper to Warrant Officer Class I.

Regular Officer Training

In future the majority of regular RE officers will possess degrees in Engineering or Applied Science, a few will have specialized in Electrical Engineering. During their post-commissioning training all RE officers attend the Electrical and Mechanical School of the Royal School of Military Engineering at Chatham for a short course, which is primarily a familiarization course in military electrical and mechanical equipment and techniques. After gaining experience with troops, a small number of officers with special aptitude for electrical and mechanical engineering are selected each year to undergo a two year course at the age of about 30. Half of this is spent at the RSME at Chatham, during which workshop practice and electrical and mechanical technology are taught, the remainder of the time is occupied in attachments to civil firms, consulting engineers or public authorities. This provides a well balanced syllabus, which is acceptable to the Institution of Electrical Engineers as providing satisfactory practical experience. Thereafter these officers will be posted to specialist E & M appointments in the rank of Captain or Major for at least two years, thus obtaining the necessary experience at supervisory level. They will then be expected to apply for membership of the Institution of Electrical Engineers.

Quartermaster (Electrical and Mechanical Officers)

Selected Clerks of Works (Electrical), who have reached the rank of Warrant Officer Class I, are commissioned into this category at the age of about 40. Such officers are primarily required to supervize the installation of electrical and mechanical equipment in the field and its operation, maintenance and repair. Recent experience in Aden and Borneo has shown how extremely versatile and capable these officers are. Such officers are commissioned into the rank of Captain and may rise to Lieut-Colonel.

Clerks of Works (Electrical)

As soon as a tradesman has obtained his second class trade classification (as Electrician RE), and his first class Certificate of Army Education and has reached the rank of Corporal, he becomes eligible for selection for the Clerk of Works (Electrical) Course. In view of the high standard demanded on this course, entry is severely restricted. The course lasts for eighty-one weeks and candidates have to pass a number of intermediate tests at approximately three monthly intervals. This course is widely recognized as producing an extremely high quality product. We hope that in the future it may be possible to get it recognized as the educational requirement for membership of the Institution of Electrical and Electronics Technician Engineers. Successful students are granted the rank of Staff Sergeant on completion of the course, and subject to satisfactory service proceed automatically to the rank of Warrant Officer Class II seven years later and thence by selection to Warrant Officer Class I, and as has already been stated selected CWs are commissioned as E & MOs.

Other Ranks

The Army trade of Electrician RE is a general purpose trade covering equipment maintenance, field power station operation, line erection, wiring and cable jointing. The Army has, for some time, realized the importance of categorizing recruits according to their intelligence rating. Only those with the aptitude and ability, which has been established by careful selection tests, are eligible for training in this trade into which they are recruited from two sources. The chief source is the Army Apprentice College, Chepstow, where boys are admitted on leaving school and given further education with a high technical content until they are 17½ years old, which is the age for admission to the Army as adult recruits. This education is aimed at "O" levels and City and Guilds examinations. A high standard is attained both as regards education and technical skill. Those boys, who are studying to become electricians, should reach the Class III standard before leaving the school and in addition usually cover the theoretical content of the Class II syllabus.

The second source of recruitment is of course through the recruiting office. Adult recruits (i.e. over 17½ years old) are first given their basic military training in the Training Regiment RE at Aldershot. Recruits of the requisite standard may choose the trade of Electrician RE and will be trained as Class III tradesmen at the RSME and about 70 per cent manage to complete the course successfully. Thereafter they will be posted to Royal Engineer field units to gain practical experience in their trade, where they will link up with the ex-apprentice from Chepstow. After gaining adequate experience in the field and, if recommended by their Commanding Officer, both categories of tradesmen will return to the RSME for an up-rating course of twenty-three weeks to Electrician RE Class II. Again all do not pass. Students are given every encouragement to qualify for City and Guilds Certificates. Direct entry to CG 51 Electrical Installation Work Courses B and C and CG 52 Electrical Engineering Practice is given according to the man's trade classification. After further experience, such tradesmen may later return for Class I training or, if selected, may go direct to a Clerk of Works Course. Class I Electricians RE are eligible for the skilled section of the Electrical Trades Union, when they leave the Army, whilst Class II tradesmen with adequate practical experience will also be considered on their merits.

This brief summary of the training of officers and men of the Royal Engineers in Electrical Engineering indicates the high standards, which are maintained at all levels, and the high degree of skill and versatility needed to enable us to meet our commitments in the field.

SECTION 4—EQUIPMENT IN SERVICE

Generating Sets of 62·5 kVA Output or Less

Generating sets within this category are held by the Royal Army Ordnance Corps. Many of such sets are integral with the equipment, for which they provide power, and as such are excluded from the scope of this paper. Within this range there is a large number of sets in service, differing in characteristics and outputs. Typical equipments held in comparatively large quantities are as follows:

3½ kVA set (Fig 1)

These lightweight sets are primarily designed as an airportable power source for communications equipment. Normally two of these sets are mounted in the standard ½ ton 2-wheeled trailer. Such sets are normally connected to a change-over switch unit, thus permitting rapid switching from the operating set to the standby set in the event of breakdown. The engine is an air-cooled horizontally opposed twin-cylinder petrol machine running at a governed speed of 1,500 rpm. The generator is a 4-pole self-excited unit rated at 250 V, 15 amps, 50 Hz.

5 kVA set (Fig 2)

This set is mainly used to provide power for the 3 kW field lighting kit and is widely held by units at squadron/company level. It comprises a compact petrol engine coupled to a 240 V, single-phase 50 Hz generator. The set is fitted within a skid-mounted frame and can readily be lifted on or off any available vehicle.

6 kVA set (Fig 3)

This set is the "big brother" of the 3½ kVA set and is designed as a general purpose power supply for signals installations. Normally two sets are mounted in the standard 1 ton 2-wheeled trailer with change-over switching arrangements. The engine is an air-cooled vertical twin-cylinder machine with a governed speed of 1,500 rpm. It is coupled to a dual voltage alternator rated at 6 kVA, 240/120 V, single-phase 50 Hz.

10 kVA single-phase set (Fig 4)

This is a general purpose set for communications equipment and for use with the 10 kW field lighting distribution kit. It comprises a water-cooled 4-cylinder 4-stroke diesel engine, running at a governed speed of 1,500 rpm. It is coupled to an alternator of the dual voltage type with a rotating armature having series/parallel windings. It is rated at 10 kVA 240/120 V single-phase 50 Hz. The set is mounted on the same standard 1 ton 2-wheeled trailer, as the twin 6 kVA sets described above.

10 kVA 3-phase set (Fig 5)

This is the smallest 3-phase generating set in service, and was designed to meet the requirement for an independent power source for REME machinery vehicles. The equipment is secured to a skid base and may be mounted on a modified 1 ton 2-wheeled trailer. The 3-cylinder diesel engine is rated at 33 bhp at 2,000 rpm and is directly coupled to a flange mounted alternator. Excitation is obtained by reciti-fied a.c. and voltage control by magnetic amplifier. The distribution panel is fitted with a 3-phase 4-pin socket, a single-phase 3-pin socket and a 24 volt 2-pole socket —the latter giving a d.c. supply for battery charging. The off-trailer weight is just over 1 ton.

27·5 kVA set (Fig 6)

This is a skid mounted set, which is normally carried on the standard 4-wheeled 2 ton trailer. The set is designed as a general power source for headquarters in the field and is dual frequency. The engine is a 4-cylinder 4-stroke diesel engine, and is coupled to a 3-phase alternator rated at 27·5 kVA, 415/208 V,50/60 Hz. The switchboard is fitted with synchronizing lamps to enable a number of sets to be operated in parallel.

62·5 kVA set (Fig 7)

This is the largest generator set held by the Royal Army Ordnance Corps. It is mounted on a single skid, and weighs 9,500 lb. It comprises a 4-cylinder 4-stroke water cooled diesel engine coupled to a 3-phase alternator rated at 62·5 kVA, 415/208 V, 50/60 Hz.

Generating Sets Over 62·5 kVA Output

Such sets are held by the Royal Engineers for the provision of power for general purposes in the field. All sets within this range are skid-mounted, generate 3-phase power, and are fitted with integral control panels with synchronizing lamps.

Currently there are only two sizes of sets held in stock in significant quantities:

120 kW set (Fig 8)

This set is designed to generate power at dual voltage (415/240 or 208/120 volts), and dual frequency (50/60 Hz). It is mounted on a single skid weighing 9 tons and may be operated directly on a level site in the field. Three or four sets are usually grouped to form a field power station for a small unit camp.

300 kW set (Fig 9)

This set is designed to operate at dual voltage (415/240 or 208/120 volts) single frequency (50 Hz). It is mounted on two separate skids. The first, weighing 16 tons, carries the engine and alternator, whilst the second, weighing 8½ tons, carries the auxiliaries, including the compressor and air bottle for starting. The set is designed to operate over a wide climatic range, and is equipped for cold weather starting by ether capsule, with preheating of engine oil and cooling water. The set does not require to operate on prepared foundations and may be placed directly on a gravel bed. Distribution is normally by medium voltage overhead cable, but transformers of suitable ratings are held to enable power to be transmitted at 3·3 kV, 6·6 kV, or 11 kV, where the distances warrant the use of high voltage distribution.

Power Generation at 400 Hz

Section 5 of this paper deals with the development of 400 Hz generators and equipment. One such equipment, an electrical power take-off on the Amphibious Tracked Personnel Carrier FV 432 (Fig 10), is already in service with the Army.

DC power for the vehicle is provided by two alternators working in conjunction with a rectifier arrangement. The system differs as between Mark I and Mark II vehicles.

Mark I

The engine drives two alternators with built-in rectifiers. Carbon-pile regulators control the outputs. Each generator supplies a separate system, and there is no connexion between the two.

One alternator supplies the automotive and ventilation requirements; the other supplies the requirements of the radio station. The output is 100 amperes each at low engine speeds. The radio alternator is capable of supply 400 Hz power when its connections are re-arranged by a harness change-over arrangement. The engine must be run at 2,100 rpm to obtain 400 Hz. Alternating current is supplied direct from the phases through a suitable transformer, and as the regulator receives a fraction of the system voltage, the latter rises to give 208 volts at the output socket. 4·5 kVA is available, and a limited amount of d.c. is fed into the system to maintain batteries.

Mark II

Two 3-phase, 6-pole alternators are gear driven from the main engine and cooled from the lubricating oil system. The gear drive ensures that the machines do not vary in phase relationship, and they are paralleled to the a.c. side. The combined output feeds into a common rectifier arrangement, producing 200 amps at 28·5 volts d.c. at lowest engine speeds. The full output is necessary for certain applications. When 400 Hz supplies are required, one alternator is detached from the system by a harness re-arrangement. The power is taken direct from the phases through a suitable transformer and, as in the case of the Mark I system, the regulator is supplied with a fraction of the system voltage to give 208 volts, 400 Hz at the output socket, the engine speed being maintained at 2,700 rpm. The rated output is 12 kVA. The remaining alternator continues to supply 100 amps d.c. into the vehicle system. Single generator arrangements, capable of simultaneously supplying alternating current and direct current as in the Mark I case are possible, but these have yet to be employed. These vehicle systems were developed by the Fighting Vehicles Research and Development Establishment.

Field Distribution

For lighting temporary camps a 240 volt, 3 kW, 2-wire lighting kit was introduced in the 1950s. The kit, packaged in three field transport cases, comprises leads, connectors, junction boxes, lamps and shades and flat twin cable on which lamp sockets with prick-through connectors can be festooned as required. To extend the scope of the lighting kits for larger installations, a 2-wire 10 kW distribution kit was added for use with the 10 kW single-phase generator mentioned above. This kit has 40 amp twin-conductor main cables fitted with suitable terminations and distribution boxes, with 13 amp fused outlets conforming to BS. 1363 dimensions, but without fused plugs. Connectors and distribution boxes are phenolic mouldings and provision is made at the distribution box (and at the junction boxes of the 3 kW kits) for connexion of a local earth spike if power tools or other 3-wire earthed appliances are used.

Other Electrical Equipment

Amongst the items of electrical equipment developed by the Army for Service use, mention may be made of Electrical Target Equipment. Rifle and machine gun target practice is an important training commitment. The laborious task of marking and repairing targets by butt parties has now been eliminated by electrically-operated equipment, which responds automatically to the strike of shot, the hits being counted remotely at the firing point. A photograph of this equipment is shown in Fig 11. The targets are exposed to the marksman by electrical signals operating either electric motor or compressed air actuators, the hits being detected by inertia switches. This type of equipment has no commercial counterpart; considerable numbers are now being produced in the Royal Ordnance factories.

Conclusion

The increasing sophistication of military equipment in both the Army and RAF is inevitably leading to increased power requirements, but the need for tactical mobility and airportability militates against larger individual power sources. Although the newer equipments, described in this section, are well matched to current requirements, the larger generating sets are undoubtedly too bulky and heavy and must be replaced by more compact lightweight units. An Army–RAF working party will shortly formulate a joint military requirement for such sets.

SECTION 5—EQUIPMENT UNDER DEVELOPMENT

Background

In an earlier section Royal Engineer activities were reviewed in retrospect. Nearly all the installations described, most of them static or semi-permanent, were concerned with generating and distributing electricity using commercial equipment at mains voltage and frequency. With the transfer of responsibilities for Works Services to the Ministry of Public Building and Works, the Royal Engineers are now increasingly concerned with field equipment where very different criteria for selecting suitable equipment apply.

Mobility is a dominating factor in modern tactics and from this springs a need for the lightest and most compact equipment which can be procured or developed at acceptable cost. Field equipment must be used worldwide and commercial equipment is rarely entirely suitable for operation in all environments. In general it is not robust enough to meet the demands of mobile armies where important requirements are use in primitive conditions and transportation with minimum preparation in unpacked condition by all kinds of vehicles and aircraft. Again, field equipment need not operate on mains supplies though in some cases it is convenient if it can, and the choice of voltage and frequency can be made mainly on technical and operational grounds.

Finally, interoperability, not only between different Arms of the Services, but between friendly nations is becoming increasingly important. Standardization on a single mains voltage and frequency in the North Atlantic area is not feasible and at the present time most transportable generating sets above 15 kVA are made with the capability of changing the voltage and frequency to suit alternative North American or European commercial consuming equipments. The power supplies in British Military use are given in Defence Standard 25A, in which are listed thirteen a.c. supplies at 50, 60 or 400 Hz and three d.c. supplies.

These considerations have led to a re-assessment of the design criteria for RE and other Field equipments, giving particular emphasis to interoperability with other Armies and Services and extreme portability. In recent years designers of lightweight aircraft and weapon equipments have tended to choose systems and components requiring 400 Hz power supplies; a variety of components for this frequency is available off the shelf, not only in the United Kingdom, but in most Western Nations and the frequency is now an accepted standard for a.c. avionic equipment. The voltage used in 3-phase, 400 Hz systems is 200 volts line to line. By adopting this frequency and voltage for Army equipment, important reductions in weight are being made over a range of generating and consuming equipments used in the forward areas, and at the same time a greater degree of interoperability of forces in the North Atlantic theatre is being achieved, together with some rationalization of military equipment in UK forces.

A number of military equipments must operate not only in the forward areas but also in bases with mains power supplies. In this class, for example, are medical equipments, signals equipments, ground support equipment for aircraft and repair and test vehicles. Compatibility of consuming equipments with available power supplies will, in some cases, require voltage and frequency conversion. The need for this is linked closely with the organization and duties of the Combat Arms and is still being assessed.

Generating plant for military equipment used in the Second World War, was described in a paper read before the Institution of Electrical Engineers in 1947.[1] Many of the requirements, stated by the Services, for electrical equipment pose intractable problems, to which we have yet to find the solution. Progress has been made, however, in refinement of design, in reduction of variety of power supplies, in reduction of size and weight and, most importantly in standardizing specifications and test methods. Fig 12 compares generating sets of 1950 and 1960 vintage and a 400 Hz set for service in the 1970s.

High Frequency Portable Power Tools

The first high frequency equipment developed specifically for the Royal Engineers is a portable power tool kit for Field Squadrons. These combat units of the Royal Engineers are concerned with a variety of forward area tasks such as construction of temporary roads and airfields, helicopter landing pads, mining and demolition, and so on. Their powered equipment until recently has been compressed air percussion tools or independently engined equipments.

In the late 1950s the Director of Royal Engineer Equipment commissioned a study of the potential of induction-motored electric power tools for the tasks normally undertaken in the Field Squadrons. The report suggested that the electric tools had a number of advantages over compressed air tools and should be evaluated. Consequently, in the early 1960s, some 200 Hz power tools and small generators were obtained and distributed to Field Units for trials. Reports were favourable and subsequently a staff requirement was raised for a high frequency portable power tool kit for Field Squadrons. At this point the advantages of adopting a frequency and voltage which would facilitate standardization of power supplies with other arms, with other services and with other nations were under consideration and so an investigation was made into the possibility of obtaining the necessary range of high frequency induction motor tools at 400 Hz frequency. In the event this proved to be quite straightforward and through the manufacturers of high frequency electrical tools in this country and in Germany 400 Hz tools, based on standard commercial 200 Hz tools, were made available at only a small additional cost, the stators being re-wound with twice the number of poles. To make them sufficiently robust for field use and suitable for pan-climatic operation, a number of detailed improvements had to be made, such as replacement of 2-pole by 3-pole switches, improvement of stator insulation and detailed improvements to switch enclosures and linkages. This has been a continuing activity at MEXE for some years and a range of service type approved 400 Hz power tools, differing only slightly from commercial power tools, is now available.

The tool kit as finally approved, and now being introduced, is shown in Fig. 13. A lightweight petrol-engined generator, rated at 5 kVA and 0·8 power factor supplies through distribution cables and connectors the variety of tools shown in the photograph. Some fifteen sets of tools as shown were distributed during the development phase to units overseas in theatres ranging from Malaysia and Aden to West Germany. The trials disclosed a number of defects on the generators, but few on the power tools, despite the fact that the equipments on trial were prototypes. The voltage adopted (200 volts line-to-line, a Defence Standard for 400 Hz), was considerably higher than the voltage generally accepted as safe for industrial portable

[1] *Generating Plant for Military Equipment*, K. H. Tuson, JIEE, Vol. 94, Part II, pp. 616–28.

power tools. The motors are three-wire star or delta connected with no neutral connection; the distribution cables have five wires with two earth continuity conductors connected independently through the system from two separate points on the power tool frames to the generator frame. The generator star point is connected to frame and thence earth by an earth spike. The five-wire distribution has been adopted as a standard by the Army; if the neutral is brought out only one earth continuity conductor is used; the neutral is not earthed except at the generator frame.

A striking reduction in weight has been made in the equipment of the Field Squadrons through the introduction of electric power tools. Fig 14 shows the small generator in relation to the much heavier air compressor, which it replaces, together with a weight breakdown. The tools themselves are about the same weight as corresponding compressed air tools, but the cables are lighter than compressed air hoses. Besides being lighter the electric system has allowed certain other useful equipments to be introduced, such as temporary lighting and a high frequency welder for stick electrode welding of ferrous metals. In addition to tools forming part of this general purpose kit for the Field Engineers the special purpose tools, listed in the following Table A, have been evaluated and type approved during the past few years.

TABLE A

SUPPLEMENTARY 400 HZ TOOLS TYPE-APPROVED FOR BRITISH ARMY USE

Item	*Detail*
Grinders	Comprehensive range from collet chuck to 9 in angle.
Drills	¼/¾ in metal to 2 in wood, some multi-speed some rotary and percussive.
Breaker	Heavy concrete.
Impact Wrenches	½ in sq drive (larger sizes under consideration).
Sanders	Belt, orbital.
Planer	
Router	
Screw-driver	
Nibblers	Up to 6½ mm
Hacksaw	c/w clamps for pipe and sections.
Pumps	Submersible 300/14,000 GPH, Borehole 4 in.
Saw benches	12 in, 16 in, with metal and stone cutting discs.
Concrete Vibrator	Poker type.
Welding Transformer	230 amp max. 12SW6 to ¼ in.

Lightweight Transportable Generating Sets

A mobile Army relies to a great extent on dispersion to minimize the consequences of enemy attack; dispersion and speed of deployment preclude long distribution systems and, as a result, power requirements are met by numerous small generators linked directly to consuming equipments. The advantages are that vulnerability is reduced, distribution cable is minimized, the equipment is easier to handle, more rapidly brought into use and dismantled, equipments are immune from disturbances due to switching adjacent equipments, and unserviceability can be dealt with with a smaller spare capacity. The disadvantages are that as ratings are reduced transportable generators become less economical in cost, generally heavier and bulkier per unit of power output and tend to be less reliable and less robust. Also, because of larger numbers, the maintenance commitment is increased.

Economies in provisioning, training and in stockholding of spares can be made if generators of different ratings are fairly homogeneous in design, and this has resulted in the concept of a family in which spare parts are inter-changeable between different sizes of generating sets. This concept is well-developed in the USA where families of military special engines and generating sets have been introduced during the past decade and are now in use in substantial numbers. A survey of the UK requirements for military equipments over the next few years has shown that the ratings which will meet many of the applications foreseen are 5, 10 and 20 kW.

To allow the widest possible use of the proposed standard family, the specification, particularly those clauses concerning characteristics of power output, was made sufficiently exacting to meet the requirements of electronic equipments. The characteristics of the various classes of military power supplies are listed in DEF 25A, the highest class of which is more demanding than the aircraft specification B.S. 2G/100. Through reducing the variety of types of special generators in field use, and standardizing on a family of multi-purpose sets, the high development cost should be recovered by large production runs.

An important consideration in all military generating plant is the type of fuel required. The uncertainty of fuel supplies in conditions of mobile warfare has resulted in a NATO policy of multi-fuel capability in vehicle engines. Good progress has been made in adapting compression ignition engines to use various grades of hydrocarbon distillate fuels, but the multi-fuel policy of the British Army has recently been modified to specify the operation of compression ignition engines on aircraft turbine fuels and vehicle diesel fuels only—not on vehicle gasoline. Most of the fuel consumed in military operations, and therefore the fuel most likely to be in bulk supply, is aircraft fuel (turbine wide-cut gasoline or turbine kerosene). It is, therefore, important that ground equipment should have the capability of using aircraft fuels and this applies particularly to ground generating equipment. Many compression ignition engines can be modified to accept the two types of turbine fuels, but CI engines are too heavy to meet the weight requirement specified for this family of generating sets. A project study suggested that the requirement could be met by coupling lightweight spark ignition piston engines directly to 8-pole 400 Hz generators running at the synchronous speed of 6,000 rev/min. Research into the multi-fuel capability of spark ignition engines also suggested that the aircraft distillates might be used satisfactorily up to modest compression ratios without detonation, provided adequate turbulence was induced in the combustion chamber, and provided the fuel was properly atomized. It was therefore decided to select a family of lightweight, high speed, spark ignition piston engines and to develop them into a range capable of running on aircraft turbine fuel.

The second column of Table B is a summary of the salient features of the development specification. As no commercial equipment approached this requirement, development was called for of engines, alternators and regulators and various ancillary equipments. For the small production required for many military equipments, the development of special engines *ab initio* is uneconomical. An exception is in the case of engines required for armoured vehicles where the technical requirement cannot otherwise be met. For this family of generating sets it was necessary to design around existing engines, which might be modified for the multi-fuel requirement. Collaboration with industry resulted in the selection of a range of engines which could be rationalized to provide a useful degree of commonality in components and to embody fuel injection and electronic ignition systems for multi-fuel development and high speed continuous operation.

Earlier studies had shown that for the ratings under consideration the lightest alternators would be salient pole, slipring machines, with static exciters. Design and development of a new range of 8-pole lightweight alternators was initiated with a firm experienced in aircraft electrical equipment. Again a high degree of commonality of parts was embodied between the three sizes, rated at 6·25, 12·5 and 25 kVA. The alternators are ventilated machines specially protected against dust erosion of the windings and sliprings. The machines are larger than necessary if designed for maximum temperature rise in the windings, as additional iron is necessary to meet the low reactance requirement implicit in the specification for good waveform with non-linear loading. In addition, filters are used on the output leads to reduce harmonic content of the waveform. Excitation power is derived from the rectified output of a voltage transformer with current compensation, voltage regulation being obtained via a saturating winding on the current/potential transformer. A voltage reference circuit using zener diodes supplies the saturating winding. Voltage regulator components are common throughout the family of alternators. The 12·5 and 25 kVA alternators differ only in stack length and in excitation components. The three sizes of alternator are shown in Fig 15.

At the time of writing, development of this family of generating sets is continuing. The three sets are shown in Fig 16. The major requirements of the electrical specification have been met but prototype alternators and exciters are somewhat heavier than predicted. The main uncertainties remaining are associated with the reliability of the machinery under long term running at the high synchronous speed and with the capability of starting and running satisfactorily on aircraft fuels. The target weights for the complete generating sets have not been met but have been approached reasonably closely. In Table B are listed the target and achieved figures, together with data on comparable modern equipment in the USA. Fig 17 shows the trends in weight and size per kW of output and illustrates the advantages of SI engines over CI engines for lightweight, compact generators.

Power Supplies from Vehicles

The introduction of high frequency portable power tools into Engineer Field Squadrons coincided with the increasing emphasis being given to rapidity of digging-in by the teeth arms of the Army. A few power tools for infantry use were provided on Armoured Personnel Carriers, together with the a.c. 400 Hz power supply derived from the vehicle electrical system described in Section 4. More recently commercial equipment has been developed by the English Electric Company (Aircraft Equipment Division) in collaboration with the Rover Company to provide a 400 Hz power supply from the power take-off on the gearbox of the Landrover (Fig 18).

Field Distribution Equipment

In larger field installations such as tactical headquarters, comprising groups of office caravans and technical vehicles, 3-phase, 50 Hz generators have become the standard power source owing to the comparatively high power demand. The single-phase distribution kit, described in Section 4, has been found inconvenient in this situation. Balancing of 3-phase loads at the generator presents difficulty and lately an experimental 3-phase, 40 amp distribution kit has been introduced for this situation. The system is five-wire throughout comprising multicore cables, commercial moulded-rubber connectors and glass reinforced plastic junction boxes protected by 40 amp circuit breakers which provide facilities for 3-phase spur connections. Each 25 amp spur is protected by a circuit breaker. 3-phase distribution boxes with six 13 amp protected single phase three-wire outlets, two on each phase, supply single phase loads. Provision is made to plug in an ammeter with a 3-phase selector switch at any point in the 3-phase system to enable loads to be balanced.

The experimental kit shown in Fig 19 could be reduced in size with re-design. It is being evaluated only to provide information for future development.

Small Developments

A number of small developments directed at improving operational efficiency, reducing manpower and maintenance requirements and replacing obsolete equipment have been initiated in the last few years. Space will not permit a detailed description of all of these, but a few notes illustrating the scope are as follows:

TABLE B. SPECIFICATION AND PERFORMANCE OF PRECISE POWER GENERATORS 208/120 VOLT, 3-PHASE, 400 HZ

Characteristic	*British Family (under development)*		*U.S. Military Standard Range (in Service)*			
	Specified	*Achieved*	*Spark Ignition*		*Compression Ignition*	
Rating	5, 10, 20 kW	5, 10, 20 kW	5 kW	10 kW	15 kW	30kW
Engine	Multi Fuel	Limited Multi Fuel SI	Gasoline	Gasoline	Diesel	
Engine Speed	Not specified	6,000 rpm	3,423 rpm	3,428 rpm	1,714 rpm	1,714 rpm
Weight 5–10–20	250 lb–350 lb–NS	340 lb–440 lb–720	479 lb	825 lb	2,740 lb	3,500 lb
Dimensions 5 kW	2 sets in ½ ton trailer	Yes 40 × 24 × 28 = 15·6 ft³	39 × 30 × 25 = 27·6 ft³	57 × 30 × 28 = 27·6 ft³	65 × 31 × 47 = 57·1 ft³	81 × 36 × 57 = 94·1 ft³
10 kW	2 sets in 1 ton trailer	Yes 48 × 26 × 30 × 21·7 ft³	16·9			
20 kW	1 set in 1 ton trailer	Yes 56 × 32 × 38 × 39·4 ft³				
Life between overhauls	1,500 hrs min	Not yet established	1,500 min	1,500 min	2,500 min	
Voltage regulation	±2·5%	±1·5%	±2%	±1·5%	±0·625	
Steady state variation	±0·5%	±0·5%	±1%	±0·5%	±0·5%	
Voltage transient	50%	17%	30%	20%	10%	
Recovery time	0.15 sec	0·1 sec	2 sec	2 sec	0·5 sec	
Voltage modulation	0·25%	Not measurable	—	—	—	
Frequency regulation	±2·5%	±0·125%	3% max	3% max	±0.25%	
Steady state frequency	±0·35%	±0·125%	±½%	±0·5%	±0·25%	
Frequency transient	±7·5%	±2%	3% max	3% max	1·5%	
Recovery time	1 sec	1 sec	4 sec	4 sec	1 sec	
Total harmonics	5%	5·14%	5%	5%	5%	
Max Individual Harmonic	3%	3·3% (5H)	3%	2%	2%	

Blood Storage

Field surgical teams require supplies of blood plasma which must be stored at $5^\circ \pm 2^\circ$C. Storage cabinets, based on commercial vapour compression refrigerators, are being developed capable of maintaining the specified storage conditions for periods up to 10 hours without a power supply, and suitable for use in the Arctic, where blood has to be warmed, as well as in the tropics requiring refrigeration. The equipment will be robust enough for field use and transportation in military vehicles. In use power will be supplied from an engine generator, stopped and re-started automatically on demand from the equipment thermostat; a thermal delay on the generator contactor will allow the engine to warm up before the load is connected.

Food Storage

Temporary food stores are projected which can be transported in knocked-down form in aircraft and which can be erected in groups to cater for the different temperatures required by different commodities. The refrigeration plant required is readily obtainable from commercial sources but special modular construction is required to minimize the package size for transportation and to allow the stores to be erected rapidly with unskilled labour on unprepared sites.

Water Supply

In arid territories deep well-drilling may provide the only source of potable water. For very deep holes an electric borehole pump is essential.

The introduction of 400 Hz power has enabled an important reduction in size and weight of borehole pumps to be made. A 4 in. pump for depths down to 600 ft has been developed, capable of pumping 1,000 gal/h. A comparable 50 Hz pump would be four times as long. The pump is driven by an 8-pole squirrel cage wet motor at 5,600 rev/min and embodies seven identical axial stages. The motor rating is 10 kVA at 165 V allowing for cable volts drop from the standard 200 V, 400 Hz system.

Welding

The repair of equipment in the field by welding is becoming more difficult with the introduction of new high strength materials which require closely controlled welding conditions. Service welders are unlikely to receive the training and practice necessary to select the optimum controlled settings for any particular job.

Equipment is being developed for programmed welding. The optimum settings are pre-determined and the operator's choice is restricted to three possible combinations of voltage and wire feed speed; the settings appropriate to the material to be welded are selected automatically on fitting the consumable wire reel to the equipment.

The correct voltage is obtained by automatic selection of the required transformer tap. The current is a function of the wire feed speed which is determined by automatic selection of a control voltage used as a reference in the closed loop control of the wire feed motor. Correct shielding gas composition, Argon or Argon/Oxygen mixtures, is also selected for the material being welded. Pulsed arc welding obtained from controlled rectifiers is used for light current welds.

As in the case of the borehole pump the choice of 400 Hz frequency has enabled the equipment to be made quite portable. In conjunction with the Landrover power supply it offers the capability of high strength repairs in primitive environments, by semi-skilled operators.

Future Possibilities

Silent Power Generation

With the emphasis now on mobility and dispersion, increasing attention is being given to the need to conceal tactical activities in close proximity to the enemy, and to the need to keep background noise to the minimum in order to listen for enemy activity. Engine generators are noisy and becoming noisier as compact, lightweight, high speed equipments are introduced. At present the only electric power sources which are completely silent are batteries. Fuel cells, now in the research stage, are expected to be audible only because of mechanical ancillaries. For continuous power generation over long periods batteries of the requisite capacity are too heavy. Fuel cells would be relatively heavy, bulky and expensive. Most important, they could not operate on the fuels available for vehicles and aircraft without fuel reformers. Nevertheless a programme of research on fuel cells is in hand. What are the other possibilities for silent power sources?

Remarkably effective noise attenuation of conventional engine generators has been demonstrated with well-designed acoustic enclosures. Enclosure of combustion engines, however, presents problems. Engines require air in comparatively large quantities for ventilation and cooling. All of this must be introduced and expelled through noise-suppressing ducting. Forced circulation of the ventilating air is required, absorbing power and producing heat and noise. Engines require periodic attention and must, therefore, be reasonably accessible. They have to be started, stopped, monitored and occasionally refuelled, from the outside. Hazardous atmospheres can build up in enclosed spaces. The design of enclosed engine generators is still at an early stage and few quiet transportable engine generator sets have yet been made.

Direct conversion of heat to electric power is feasible but as yet unattractive except for very low power equipment, due to the low conversion efficiency and relatively high cost. Direct thermal conversion involves controlled combustion at low noise level, but offers multi-fuel potential. Thermo-electric and thermionic generators, together with fuel cells, require power conditioning equipment for voltage regulation, and in the larger powers, for inversion to a.c. Rapid progress is being made in electronic power conditioning, but in the immediate future power conditioning equipment will remain an important penalty on d.c. power sources.

Relatively few developments have taken place of intrinsically quiet external combustion engines for small power sources. Experimental Stirling cycle engine generators have been built for the US Army, as have small sealed turbo-generators, using mercury as the working fluid (steam is unsuitable for very low power single-stage turbines because of the high jet velocity and low turbine efficiency). Experimental vapour cycle turbines, using aromatic compounds and refrigerants are under active consideration in several countries. Apart from silence the sealed turbo-generator promises reduced maintenance, perhaps confined to the burner only. Eventually reduced maintenance may well prove even more important to the Field Army than silence.

Table C compares weights of alternative power sources, based on data from various published and unpublished sources. Only the first three types have been developed to the point where reliable estimates are possible.

Engines

Most electrical generators with the exception of emergency standby plant, have to operate continuously for long periods. When this requirement is associated with extreme lightness, great difficulties are encountered in selecting suitable engines. The difficulty is chronic in generators of less than about 5 kW; larger sizes now use small multi-cylinder industrial diesel engines, usually variants of vehicle engines. The installed rating, assessed from a prolonged type test of the engine on Service fuels and lubricants, must allow a useful running period between overhauls to be completed with reasonable confidence. CI engines have hitherto been satisfactory for Services generating plant but the weight is a severe disadvantage for airportable equipment. Where specially lightweight equipment is required spark ignition engines are installed but at the cost of increased maintenance and reduced operating time between overhauls. In very small generating sets lightness is usually a dominating requirement and the spark ignition engine reigns supreme; the maintenance commitment imposed by these small engines is accepted reluctantly.

During the past decade the US Army have tackled this problem by introducing a range of good quality military special SI engines with a high commonality of spare parts. The large US military engine market for such equipment offsets the very high development and tooling cost involved. No comparable high quality spark ignition engines are available from any commercial source. The cost of developing special military engines in the UK is clearly not justified for the relatively small Services requirement.

Apart from improved life there is a need for lightweight, compact, inherently balanced engines with a smooth torque, to replace the single and twin-cylinder reciprocating engines of less than 10 hp. The rotary piston engine, when fully developed, should meet this need satisfactorily.

Electrical Machines

All the a.c., and some of the d.c. engine driven generating sets embody conventional alternators, most commonly salient pole rotating field machines excited either through slip rings or by rotating exciters and shaft-mounted field rectifiers. Brushless machines, driven through mechanical constant speed drives, are almost invariably selected for aircraft a.c. systems to overcome the problem of brushwear at high altitude. As an alternative variable speed constant frequency systems using controlled rectifier power conditioning (cycloconversion), between the alternator and the supply terminals is now under development in industry. Hitherto little difficulty has been encountered in maintaining constant frequency a.c. output of ground generating sets with relatively simple engine governors. Frequency transients of appreciable magnitude, due to load switching, are not usually troublesome, and considerable scope for improved governing still remains. Electronic load-sensing governors which operate the engine fuel control in sympathy with the electrical load, have been developed for critical power supplies.

TABLE C

COMPARISON OF ALTERNATIVE ELECTRICAL POWER SOURCES AT 10 KW SIZE APPROX.

Type	*Weight lb/kW*	*Fuel Requirement*
In Service 10 kW 50 cps Generator	200	Diesel
New 10 kW 400 cps Generator	45	Limited range of distillate fuels
Silenced Conventional 50 cps Generator	250	Limited range of distillate fuels
Stirling Cycle Engine Generator	120	Multi-fuel
Rankine Cycle Turbo-Generator	50	Multi-fuel
Hydrazine Fuel Cell	70[1]	Hydrazine Hydrate
Low Temp. Hydrocarbon Fuel Cell	150[1]	Special low sulphur
Flame Heated Thermoelectric Generator	70[1]	Multi-fuel

[1] Not including inverter. Add 20/40 lb/kW for closely-regulated a.c. power.

Much development has taken place in industry in recent years in applying electronic techniques to voltage regulation and excitation of alternators. Further development is likely towards standardized modular construction of reliable compact voltage regulators and static exciters sealed for life.

Rather than any radical change in type of alternator or exciter we can look towards a number of minor, but important, improvements towards meeting Service requirements. Grease-lubricated rolling contact bearings are almost invariably fitted; their life, after prolonged storage, is limited and uncertain, due to deterioration of the lubricant. High running speeds demand positive lubrication. Totally enclosed pressure lubricated machines, possibly liquid cooled, would be advantageous. In machines designed for non-linear loads, however, magnetic rather than thermal limitations determine the size and weight. The alternator lubrication and cooling might be integrated with the engine lubrication system.

The high speed, squirrel cage induction motor is very satisfactory in power tools, and other equipments which normally embody geared drives. However, when direct drives are required at lower speed, for example to replace 50 Hz motors with 400 Hz motors, conventional core proportions in multi-pole 400 Hz motors result in low power factor and low efficiency. Alternatives are geared high speed motors, or low speed 400 Hz motors with unconventional windings. Both alternatives are being evaluated. Liquid cooling is a possibility for environment-free highly rated machines.

Developments along these lines are stimulated by Defence requirements. Electrical power generation and utilization in field conditions with transportable equipment is predominantly a military requirement, though increasing civil use of small-scale temporary electrical systems is to be expected with increasing emphasis on productivity and the growing awareness of the close relationship between productivity and the use of electrical power.

SECTION 6—FUTURE TASKS

In this final section of the paper an attempt has been made to examine the future tasks of the Royal Engineers with regard to the supply of electrical power in the field. Inevitably the requirements for power must increase to keep pace with the sophistication of modern equipment and with the higher standards of comfort, which must be provided for the soldier in the field as soon as the tactical situation permits. It is interesting to compare a US Army estimate of power requirements in Vietnam of 2 kW per man with a figure of 0·5 kW per man during the final stages of the campaign in North-West Europe in 1945. The Defence White Paper of July 1968 gives the broad strategic framework within which our future equipment and training programmes must be formulated. It is suggested that increased emphasis must be laid upon the following:

(a) *Power Supplies for Airfields*

Our intervention capability must depend initially upon the ability of the RAF to operate from permanent airfields within the theatre of operations. The existing power supplies may have been put out of action by sabotage or direct attack. The Royal Engineers must maintain the ability to provide an emergency airfield supply and to rehabilitate damaged generating and distribution equipment. Subsequently mobility within the theatres can only be maintained by the use of medium range transport aircraft, operating from the main airfield, up to forward airstrips. In such cases the Royal Engineers must be capable of installing lighting equipment at the forward strips, with very great speed, using prefabricated light-weight kits.

(b) *Provision of power supplies for a military port and Forward Maintenance Area*

Although any military operation outside North-West Europe will inevitably be air-supported in the early stages, it will be essential to provide support by sea as soon as practicable. It may therefore be necessary to develop a small port or harbour to handle military loads and to build up an adjacent Forward Maintenance Area, into which stocks of bulk petroleum, food and ammunition can be stockpiled. This may well involve the establishment of a field power station (using transportable skid-mounted sets) and a distribution network. A new range of light-weight generating sets is needed for this role.

(*c*) *Maintenance of Civil Power Supplies in an Internal Security Situation*

Situations will continue to arise, in which British troops will be called upon to intervene in conditions of civil disturbance in dependent territories. Local power station staffs may well be intimidated and prevented from attending to their duties. In such conditions the Royal Engineers must be capable of taking over the operation and maintenance of local power stations and distribution systems.

Conclusion

Whatever the precise interpretation placed upon our current strategy, it is clearly beyond dispute that the Royal Engineers must retain a viable role in connexion with the supply of electrical power in the field. Their ability to meet such power requirements in all situations and in all types of climate and terrain, may well prove a decisive factor in the conduct of whatever future operations the British Army may be called upon to undertake.

ACKNOWLEDGEMENTS

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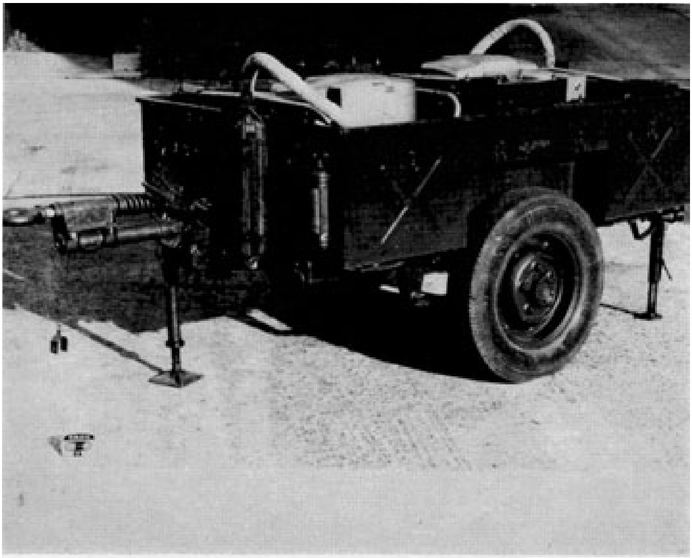

Fig. 1. Two 3½ kVA generating sets mounted in ½-ton trailer.

Fig. 2. 5 kVA generating set, single-phase 240V 50 Hz.

Electrical power for the army in the field 1,2

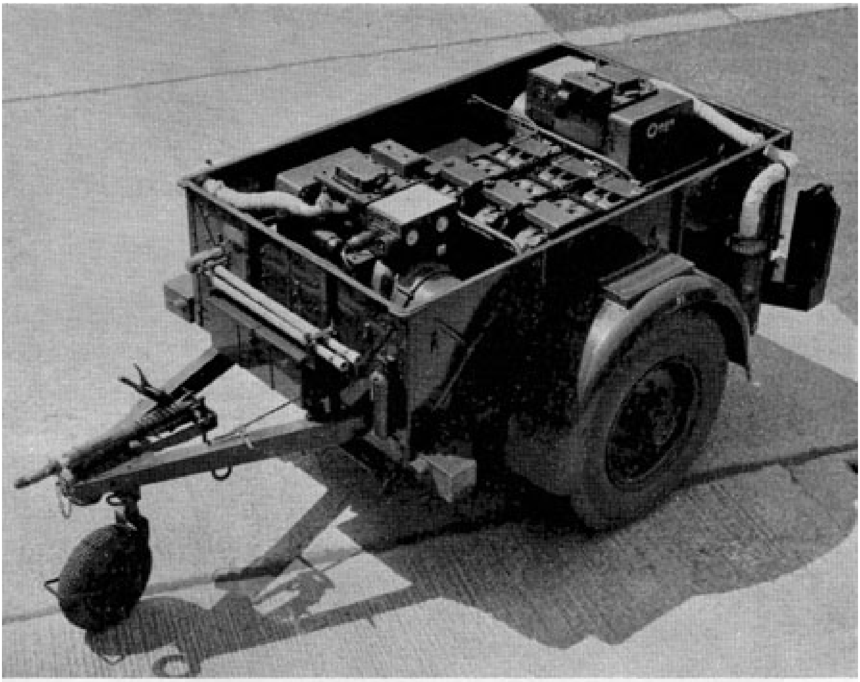
Fig. 3. Two 6 kVA generating sets mounted in 1-ton trailer.

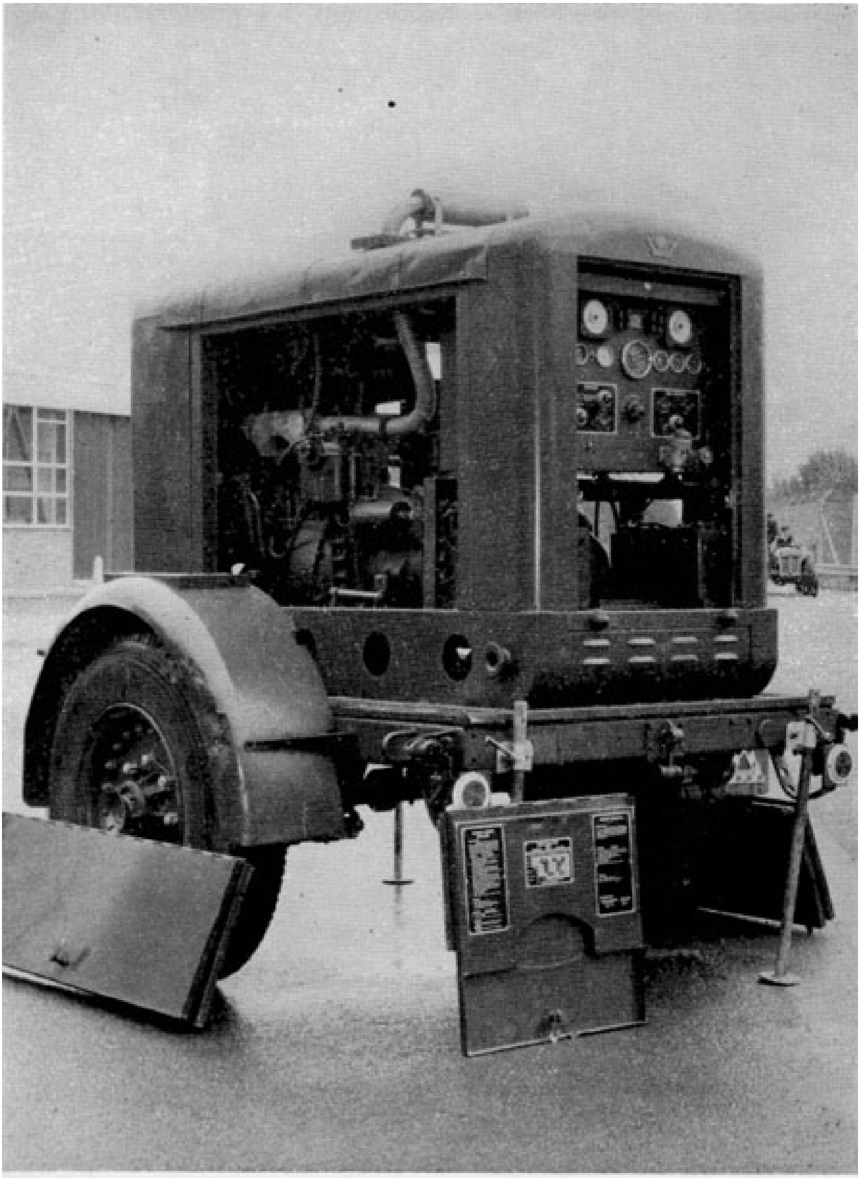

Fig. 4. 10 kVA single-phase generating set.

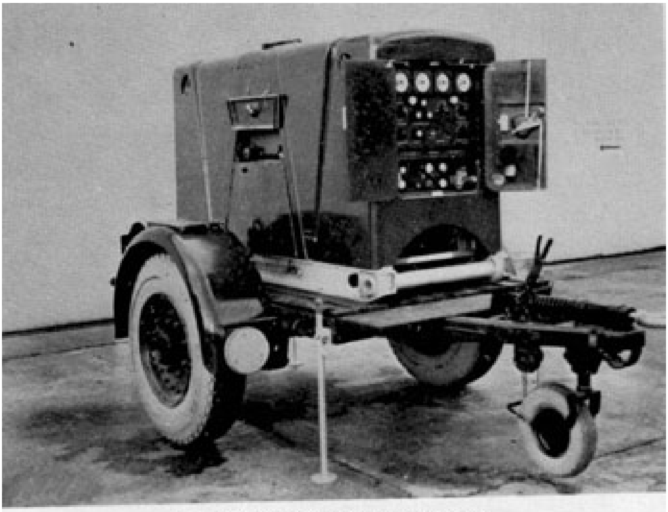

Fig. 5. 10 kVA three-phase generating set.

Fig. 6. 27.5 kVA generating set mounted on 2-ton trailer.

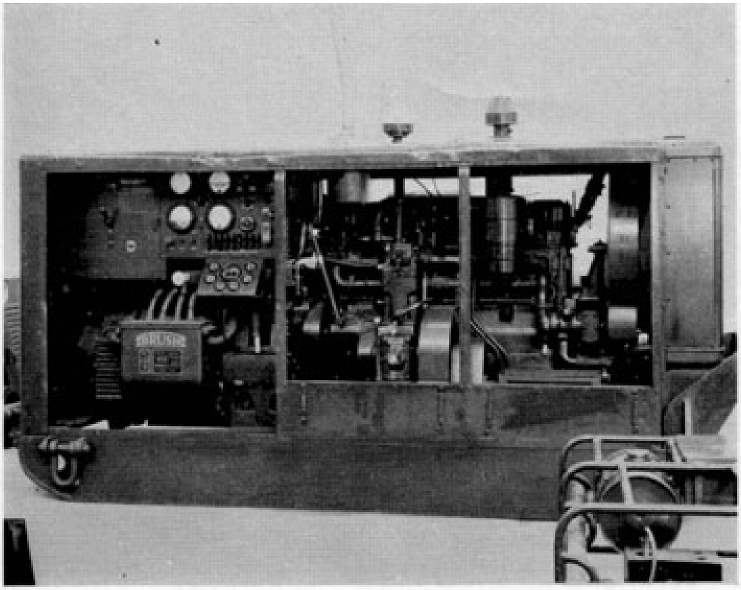

Fig. 7. 62.5 kVA skid mounted generating set.

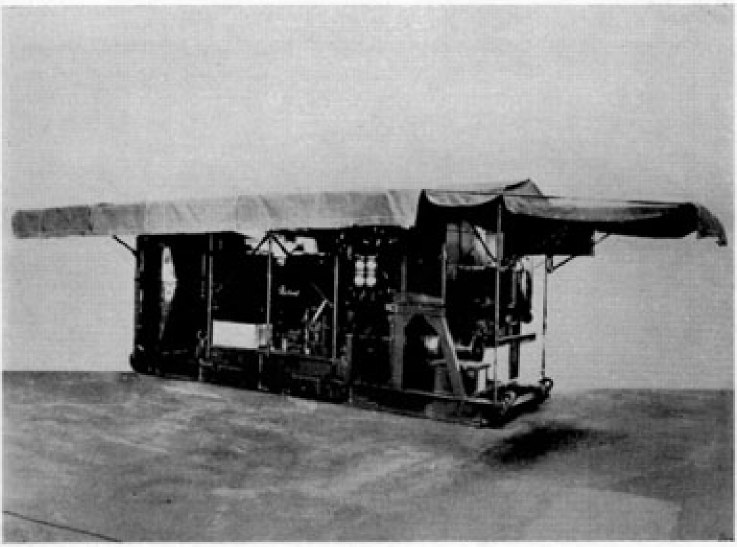

Fig. 8. 120 kW skid mounted generating set.

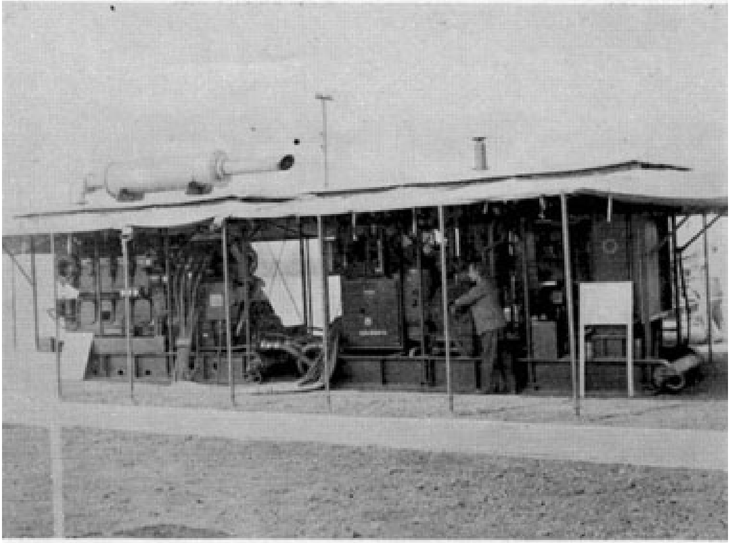

Fig. 9. 300 kW skid mounted generating set.

Fig. 10. Amphibious tracked personnel carrier, FV. 432.

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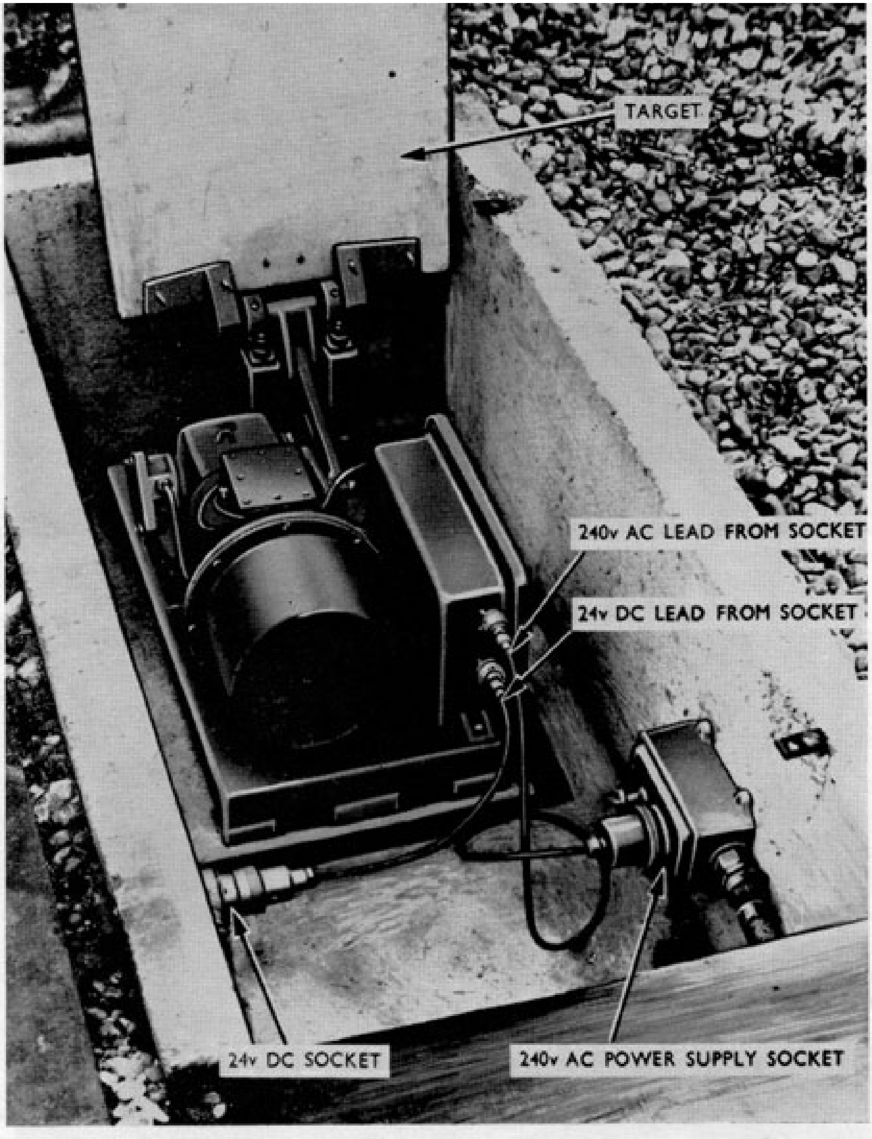
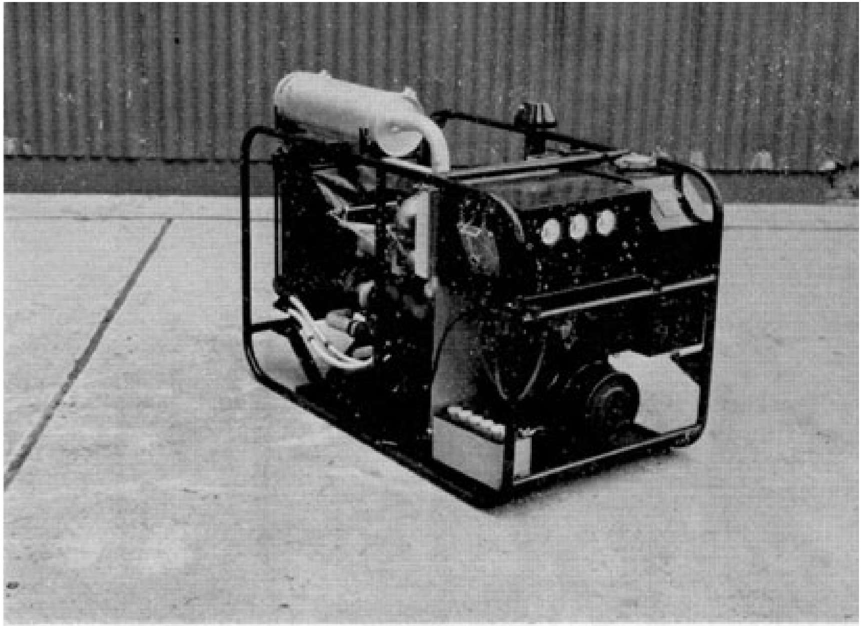


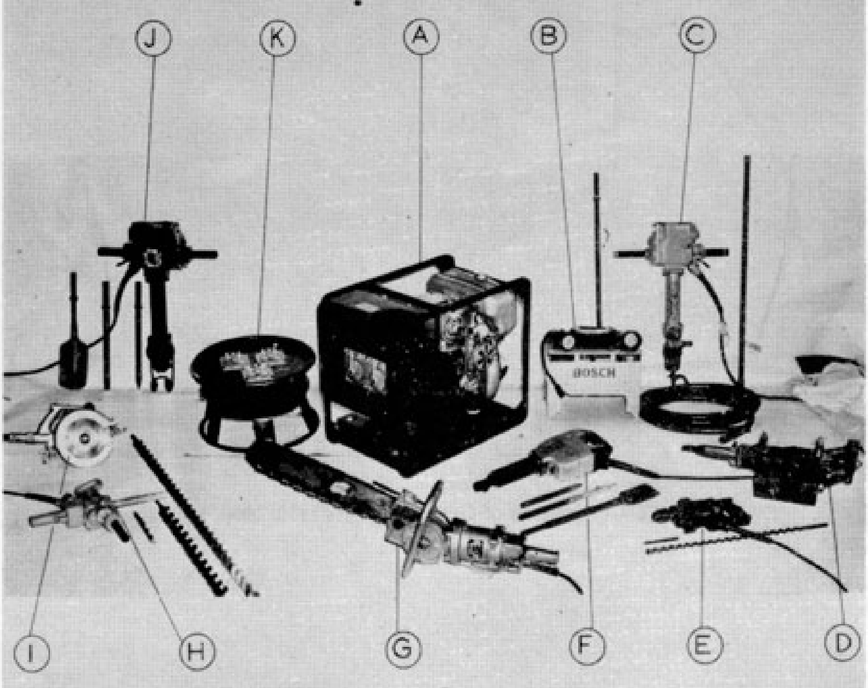
Fig. 11. Electric target mechanism installed in pit.



1970

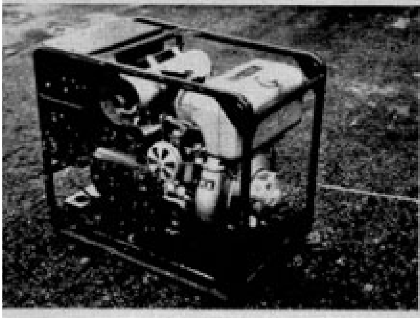
Fig. 12. Comparison of Generating Sets 1950, 1960, 1970.

400CPS. ENGINEER GENERAL PURPOSE TOOLKIT.

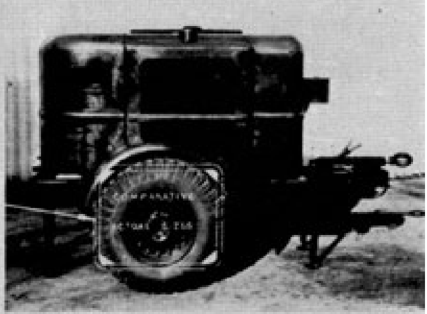


A.	GENERATING SET 5KVA, 208V, 400 CPS.
B.	BLOWER, FOR USE WITH ROCK DRILL.
C.	ROCK DRILL.
D.	GRINDER 6", WITH BENCH STAND.
E.	DRILL 3/8".
F.	LIGHT DEMOLITION HAMMER.
G.	CHAIN SAW 23".
H.	DRILL 3/4".
I.	CIRCULAR SAW 8".
J.	MEDIUM BREAKER HAMMER.
K.	CABLE DRUM JUNCTION BOX.

Fig. 13. Engineer General Purpose Toolkit.



5KVA 400 cps GENERATOR



100cfm/100 psi COMPRESSOR

400 cps ELECTRIC (LBS)		PNEUMATIC (LBS)
200	POWER UNIT	3250
60	ROCK DRILL	60
50	BLOWER UNIT	—
65	BREAKER	60
39	CHAIN SAW	31
22	DRILL 3/4"	20
8	DRILL 3/8"	6
22	DEMOLITION HAMMER	20
17	GRINDER 6"	13
15	CIRCULAR SAW 8"	12
50	CABLE 200 FT WITH JUNC. BOX DRUM	—
—	AIR HOSE 200 FT WITH FITTINGS	100
548		3572

9HP	ENGINE RATED OUTPUT	27HP
1	FUEL CONSUMPTION (GALL/HR)	3

Fig. 14. Weight Breakdown of Electric and Pneumatic Power Tool Systems.

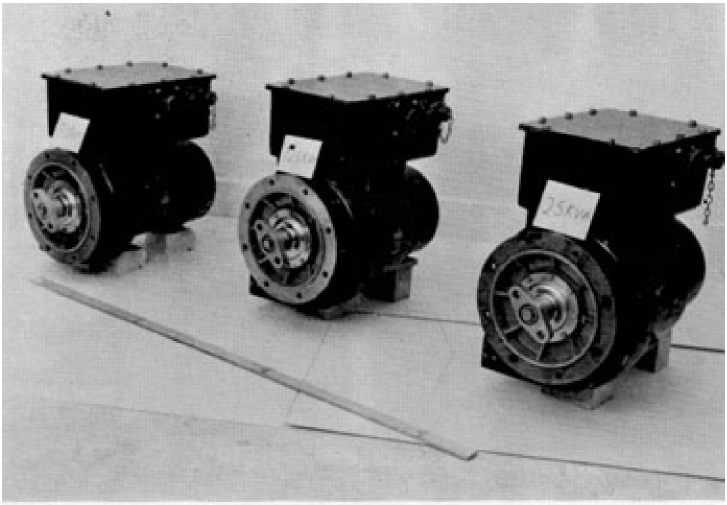


Fig. 15. Alternators for Family of Generating Sets.

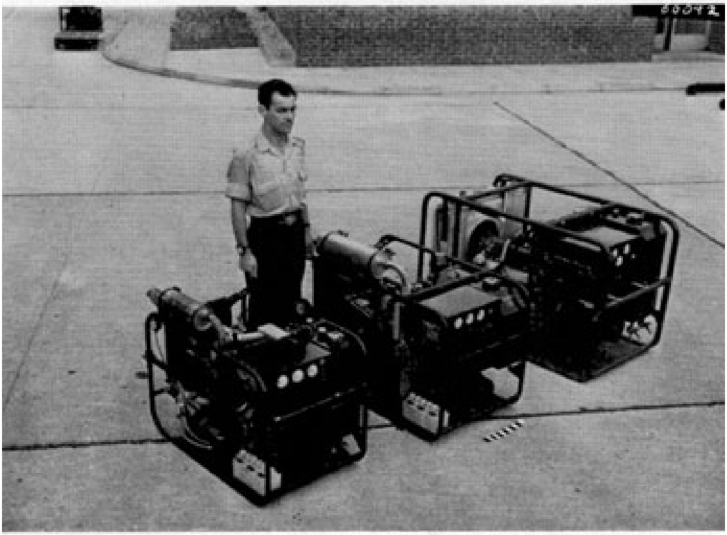


Fig. 16. Family of 400 Hz Lightweight Generating Sets.

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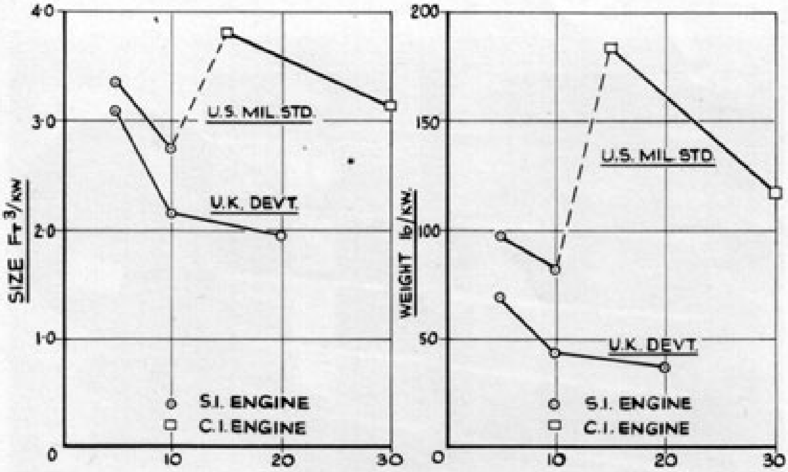


Fig. 17. Military Rating kW.

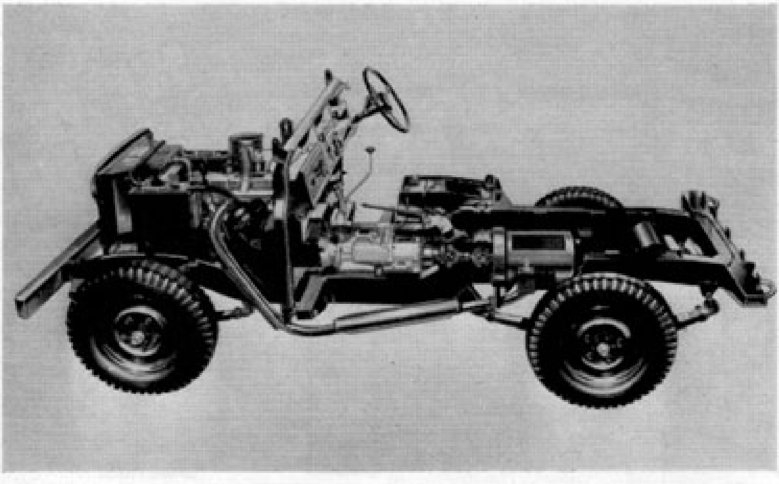


Fig. 18. Landrover 400 Hz System.

Electrical power for the army in the field 17 & 18

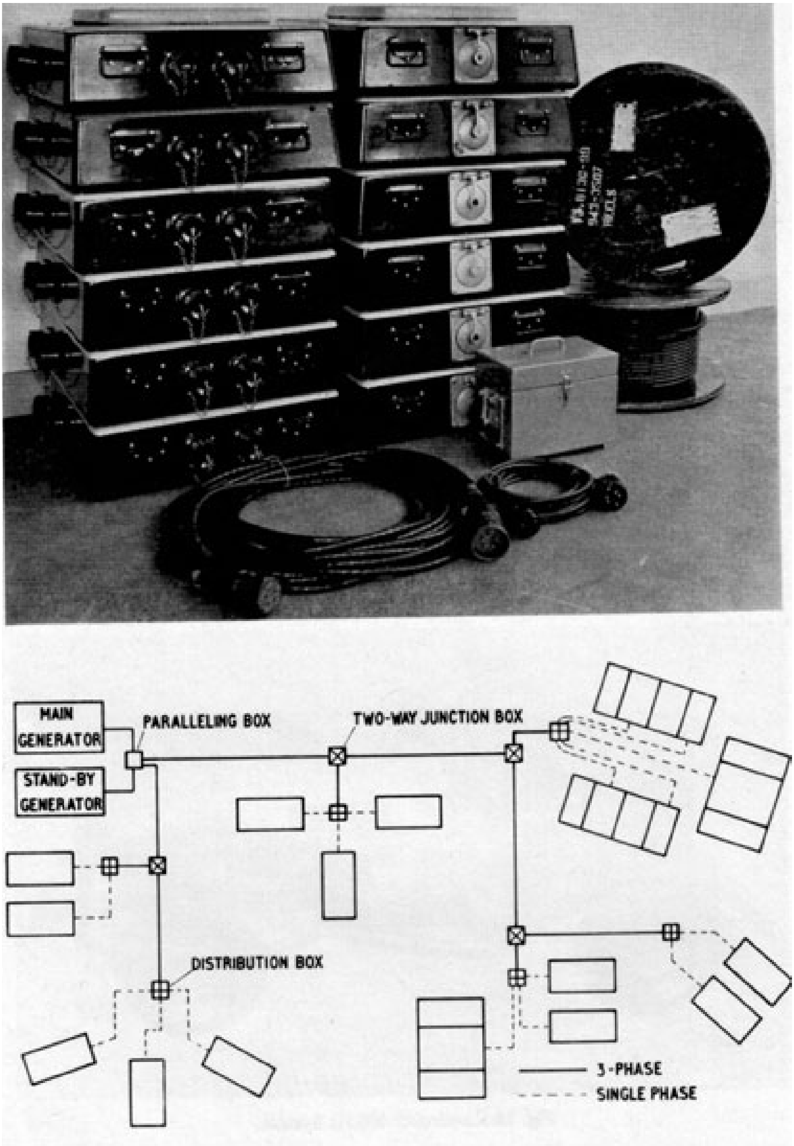


Fig. 19. Three-phase Distribution Equipment and Diagrammatic Layout.

Floods in the South West

BRIGADIER M. E. TICKELL, MBE, MC

On 11 July 1968, Commander 12 Engineer Brigade accidentally heard the 7 am news. He caught the words "flood" and "bridge down", woke up the BM and, with a vague instruction to "find out and send some of 36 if necessary", caught a train to London to attend a recruiting conference of all Chief Engineers. Recruiting is an engrossing subject, and HQ 12 Engineer Brigade took full advantage of the eight hours of freedom from interference that it gave.

By 8 pm the situation was rather different. Advanced HQ 12 Engineer Brigade, under the DAA and QMG, was in control in Devon, the Commander and BM were attending a Guest Night with 37 Engineer Regiment at Longmoor, and the Engineer-in-Chief was at Rear HQ, 12 Engineer Brigade at Barton Stacey. Not perhaps a textbook Staff College deployment, but fortunately for the man in the middle there were other activities that evening.

By this time, essential reconnaissances had been completed, 20 Field Squadron was moving to Honiton, 60 Field Squadron were alerted for the Bristol area, and RHQ and the rest of 36 Engineer Regiment were getting ready to go together with further reconnaissance parties from other units of the Brigade. Meanwhile, bridging was being loaded at Longmoor and Long Marston and the first trucks were soon on their way.

By 8 am 12 July when HQ 12 Engineer Brigade was properly established under command of GOC South West District at Taunton, the situation was as follows. Construction of the big A30 bridge at Fenny Bridges had started, setting out of the A37 Bridge at Pensford was under way, and plans were soon made in conjunction with the County Surveyors concerned for 36 Engineer Regiment to build two more main road bridges in Keynsham town and on the A303 at Marsh. A full account of the Regiment's achievements is given in following pages.

This looked after only four of the dozen or so bridges that were down or badly damaged in the astonishing flash floods that swept through the narrow valleys in a wide strip of Devon, Somerset and part of Gloucestershire. In particular, two villages, Tipton St John and Woollard had been cut in two and Upottery was virtually cut off. An eighth critical bridge north of Keynsham was down but work on that could not start until a large gas main had been diverted and other Council work completed. (The Bailey there was built in a very tidy operation by 48 Field Squadron from 38 Engineer Regiment as soon as the site was ready some ten days later.)

We knew on 12 July that 71 (Scottish) Engineer Regiment (V.) were arriving on 14 July for a fortnight's bridging camp at Wyke Regis. There were no other uncommitted field squadrons in the South of England and the chance was too good to miss. There were three bridges and three squadrons and each deployed almost straight off the train from Scotland on to its allotted site and built a model bridge in almost record time. The Regiment should be allowed to tell its own story, which is an exciting one in its own right.

The construction of the eight bridges of average span over 100 ft involved the Brigade HQ, two complete Regiments and a seventh field squadron, about 100 load carriers from four different RCT units, the TAVR Movement Light Battery, some 500 tons of EWBB and HGB (all of which had to be issued and loaded by the ESG organization), and some helicopters. South West District fathered the whole force so efficiently that administration was never a serious problem and the Headquarters staff worked flat out to help us.

It is too early to draw firm conclusions from this operation, particularly with the subsequent South East floods fresh in our minds and a Brigade study period on "Disasters" pending. There were many faults which require rectifying. However, some quick impressions might be of interest:

(*a*) The cheerfulness and encouragement of the local people in spite of the terrible damage that the floods had done to their homes.

(*b*) The very close working relationship that was established between the county engineers and their uniformed counterparts on all sites. And the strong support from the police, who had an unenviable job.

(*c*) The relatively few hold-ups on site through equipment delays. Great credit is due to the stores organization (who should also write their own story), and to the RCT drivers, many of them trainees. They drove long distances over disrupted and crowded roads by day and night with hardly a mishap.

(*d*) The very different problems posed by a civil bridge from those of the same bridge under war conditions. Site limitations caused by services and rebuild plans, for example, only enabled us to build a two-way heavy girder bridge on two sites and we re-learnt our Bailey very fast. Ramps, surfacing, safety of footwalks, etc. required special care.

Note. An article by Lieut-Colonel J. N. Elderkin, RE on the activities of 71 (Scottish) Engineer Regiment (V) appeared in the November 1968 issue of *The Sapper* and in the September 1968 issue of the *T & AVR Magazine*. The November 1968 issue of *The Sapper* also contained an article by Captain A. Nesbitt, RE describing how the Central Engineer Park at Long Marston issued the vast quantity of equipment required to deal with the disaster. EDITOR

36 Engineer Regiment and the West Country Floods

LIEUT-COLONEL J. N. HOLDEN, RE

DURING the period 9–12 July a deep low-pressure trough passed rapidly northwards over the Devon coast, veered north-east in a wide arc over Taunton and Bristol and departed over the Wash towards Norway. It brought gale-force winds and rain of monsoon intensity, leaving in its wake a trail of ruined crops, damaged buildings, wrecked vehicles and washed out bridges.

The area which suffered most was the West Country. Four inches of rain fell in the Honiton, Taunton and Bristol areas during the night of Tuesday/Wednesday 9/10 July. Water poured off the Blackdown and Mendip hills and produced dramatic flash floods in several rivers that are normally little more than pleasant trout streams. Many bridges were swept away.

On the morning of Thursday 11 July, 36 Engineer Regiment was pursuing its normal training in the Maidstone area with nothing but pre-planned commitments in view. On the afternoon of Tuesday 16 July, 36 Engineer Regiment was again pursuing its normal activities in the Maidstone area. In the intervening time the Regiment had replaced the four most important bridges destroyed by the floods in the West Country two hundred miles away.

More bridges were subsequently built by other units, and the complete operation was given the name Operation "Giraffe".

This article describes the part played by 36 Engineer Regiment in Operation Giraffe, and highlights certain points of interest and lessons learnt during the operation.

After a brief word about the regiment, the deployment, tasks, and command and control arrangements are dealt with. Lessons learnt and points of interest are mentioned as they occur. Nothing new or earthshaking emerges. But the commitment of a regiment with three field squadrons and elements of a field support squadron to an unexpected and distant task does not occur as often as we should all like. It is hoped that an account of how this happened to one regiment may be of interest.

36 Engineer Regiment is a Strategic Reserve Support Echelon unit under the command of 12 Engineer Brigade. It consists of RHQ, 20, 24, 50 and 60 Field Squadrons and 61 Field Support Squadron. RHQ and three field squadrons occupy the new barracks at Invicta Park, Maidstone. The fourth field squadron is based in Kingshill Barracks, Hoo, and the field support squadron occupies the Old Barracks, Maidstone. Apart from the squadron in Kingshill Barracks, which obviously must have its own MT and plant with it, the Regiment runs on the "Centralized System". All MT is physically concentrated and controlled by the Regimental MTO. All plant is concentrated and controlled by the OC of the support squadron, through the plant troop commander. Training and operations are controlled from a permanently established Command Post under the Intelligence Officer. It is so organized that it automatically forms Tac RHQ and/or CO's Rover Group whenever the Regiment moves out of barracks.

On the morning of Thursday 11 July the deployment of the Regiment was as follows: 20 Field Squadron (Major P. J. Walsh)—local training in preparation for an exercise in Scotland. 24 Field Squadron (Major D. T. Ives)—Project Officer, HQ Troop Commander, one senior NCO from each troop and forty-five sappers, in Canada as advance party for Exercise Water Leap; one troop completing a road project in the RSME and one troop carrying out a small improvised timber bridge project at Petworth, 80 miles away. 50 Field Squadron (Major A. Whitehorn)—six months unaccompanied tour in Gibraltar and Cyprus. 60 Field Squadron (Major I. G. Graham)—one troop (+) supporting RSME; a detachment carrying out a local project; and a detachment preparing a demonstration for the ACF scheduled for the coming weekend. 61 Field Support Squadron (Major D. J. R. Cook)—approximately 25 per cent of Plant Troop deployed locally on projects.

The CO, whose successor was due to report on the Monday, had set off on his final, "look at the training". He had left with OC 24 Squadron at 0700 hrs for Petworth, leaving the 2IC (Major D. P. Cadoux-Hudson) to run the routine weekly conference.

At 1000 hrs on Thursday 11 July, a telephone call from the Brigade Major 12 Engineer Brigade informed the Regiment that serious flooding had occurred in the West Country. Bridges at Fenny Bridges, 4 miles west of Honiton on the A30 and Pensford 7 miles south of Bristol on the A37 had been washed away. The Regiment was to be prepared to deploy one field squadron to replace these bridges, using either HGB or EWBB. The squadron was to be prepared to move to Heathfield Camp at Honiton at 1800 hrs that evening. (Heathfield Camp is occupied by 1 RWF.) Two reconnaissance parties were to be organized immediately. One for Fenny Bridges to leave the regimental square by Sioux helicopter at 1130 hrs, the second for Pensford to leave Rochester airport by Beaver at the same time. Transport from Bristol airport to Pensford would be arranged by HQ 12 Engineer Brigade. Each party was to meet an engineer from the local authority on site. Reports were to be made by the OIC each recce party direct to HQ 12 Engineer Brigade as soon as the recce had been completed. Bridging equipment, transport and cranes would be organized by HQ 12 Engineer Brigade.

The second in command needed only a few moments thought to appreciate that 20 Squadron was the obvious choice for the job. It was carrying out squadron training locally and could be quickly concentrated. The OC and squadron management were immediately available in barracks. Certain preparations for the squadron move were already in hand for the forthcoming exercise in Scotland, and although it had not taken part in the recent regimental exercise which had included bridging, it had done some bridging training earlier in the year.

OC 20 Squadron was accordingly ordered to organize the two recce parties, and to prepare his squadron for a move to Honiton by 1800 hrs. His task on arrival was given as "Construction of bridges at Fenny Bridges and Pensford". He was given half an hour to issue preliminary orders. He was then to return for a quick "O" Group which the IO was arranging for the 2IC.

The "O" Group was clearly necessary for co-ordination. It's composition was:

OC 20 Squadron	
OC 61 Field Support Squadron	Plant and crane ops, life jackets, assault boats and OBMs, project lighting.
RMTO	MT, res POL, refuelling arrangements, route cards.
QM	Foul weather clothing, security of empty barrack blocks.
Specialist Messing Officer	Rations.
RSO	
Unit Families Officer	Welfare of separated families.
QMSIs	One to accompany Squadron.
RSM	
Adjt	A matters and PR.
IO	Maps, pamphlets, co-ord with 1 RWF.

It will be obvious that this O group was mainly concerned with launching 20 Squadron to Honiton. One important point was, however, covered. Clear orders were given that the OIC each recce party was to report to RHQ by telephone immediately after submitting his report to HQ 12 Engineer Brigade.

Having launched 20 Squadron, the 2IC considered what the next move was likely to be. Practically nothing was known about the extent of the flooding and the damage that had been caused in the West Country. He thought it prudent, however, to prepare for further calls for assistance. In the light of the other two squadron's commitments it seemed on balance that the order of batting was 60 Squadron and then 24 Squadron—provided that the RSME could release the strong troop of 60 Squadron in support of the Field Engineer School (in fact, HQ 12 Engineer Brigade had anticipated this and requested the release through MOD). The RSME not only agreed to this at once; they also most helpfully undertook to cover 60 Squadron's cadet commitment as well.

OC 60 Squadron was therefore put in the picture and warned to be prepared to move his squadron to the West Country for a bridging task. The timing of the move was uncertain but was thought to be unlikely to be before the next day.

On the COs return at 1530 hrs, he was immediately briefed by the 2IC. By this time orders had been received from HQ 12 Engineer Brigade that 20 Squadron was definitely to move to Honiton at 1800 hrs. No other information was available and nothing had been heard from either of the recce parties.

On reassessing the situation it seemed that each bridge was a probable squadron task. Since they were both on "A" roads it also seemed that the priority for replacement would be the same. Furthermore they were 80 miles apart across what was by implication flood ravaged country. 60 Squadron was therefore put at 6 hours notice to move to the Pensford area with the probable task of replacing the washed out bridge on the A37. (The CO's guess, wrong as it turned out, was that no move was likely before the next morning.) The second QMSI was also warned that he would be attached to 60 Squadron if they moved.

Assuming that two field squadrons would be deployed, there would be a need for Tac RHQ to move to the West Country also. This presented very little problem and the IO was ordered to be prepared to move with Tac RHQ from 0900 hrs the next day. It also seemed prudent to anticipate flood relief tasks other than bridging. It seemed reasonable to leave the troop of 24 Squadron at Petworth to get on with their project. OC 24 Squadron was therefore ordered to put his other troop at 4 hours notice to move to the West Country from 0900 hrs the next day, with the task of flood relief other than bridging. The School of Infantry Warminster seemed well placed as a base for this troop, and the Regimental 2IC immediately cleared this with them. It also seemed possible that elements of Plant Troop and Stores Troop from 61 Support Squadron might be required. OC 61 Support Squadron was therefore warned of this possible commitment. He was given no timing for this beyond the general indication that it was likely to be "Sometime tomorrow". It was obvious that further orders might come in during the night. The IO was therefore ordered to arrange for the CP to be manned throughout the night, and for key individuals to be available at short notice.

The 2IC, and the OC of the Field Support Squadron then set about laying on rations, assault boats, OBMs sand bags, lifejackets and so on, while the CO talked to the BM 12 Engineer Brigade.

No information had come in from either of the recce parties. Neither the BM nor the CO, therefore, had very much to go on. The BM was informed of the measures taken by the Regiment, and a Beaver or helicopter flight to the West Country was arranged for the CO next morning.

It was now, at about 1800 hrs, that the first lesson began to emerge. The two recces had in fact been completed. The results had been given to the DAA and QMG, 12 Engineer Brigade, who had established advance HQ, 12 Engineer Brigade in contact with the HQ South West District emergency control room at Taunton. He was of course desperately anxious to start ordering up bridging and bridging transport. For this he needed the results of the recces. Once he had these he worked to such effect that construction was never significantly held up for lack of bridging. The point is, however, that nothing of this was known to CO 36 Engineer Regiment in Maidstone. The recce parties had important information. Quite apart from the technical details of each bridge site, they knew the general flood situation, which was unusual, the state of the roads and communications generally, the local control set-up and the steps taken to order up bridging as well as the approximate time it was likely to arrive. All this would have been most useful to the CO and would have been a very considerable help to him in his efforts to read the situation. (Each recce party did in fact report in by telephone to its squadron HQ giving technical details of their bridge sites.)

The lesson is clear. Information is vital to commanders. Recce parties dispatched with orders to report by radio or telephone must pass their information to a responsible officer. Their report must include *all* useful information, and, if not returning to base immediately, they must ensure that their commander knows how to contact them again.

At 1830 hrs then the management had gone home for a late tea, 20 Squadron was on its way to Honiton and the rest of 36 Regiment was working with ordered calm (or frantic haste, depending on the point of view).

At 2000 hrs further orders were received from HQ 12 Engineer Brigade. 20 Squadron was to build a Bailey at Fenny Bridges and 60 Squadron another at Pensford. The setting out party for Pensford was to be on site as early as possible next morning (12 July). The remainder of the Squadron was to move from Maidstone at 0900 hrs on the 12th.

OC 60 Squadron was quickly contacted and given the appropriate orders. The OC and one troop in fact set off for Pensford at 2300 hrs. The OC travelling independently arrived on site at about 0500 hrs, followed by the troop at 0830 hrs.

With a reminder to the IO that Tac RHQ would now certainly be required to move the next day, the CO went home to pack his kit. While doing this he reflected, in a moment of wildly unrealistic optimism, that his successor would have to take over an absent regiment from the Quartermaster.

The early morning news and newspapers on the 12 July gave extensive coverage to the floods. By 0800 hrs the CO had formed a very clear impression that a major disaster had struck the West Country. There seemed to be raging torrents everywhere and widespread flooding over a large area, with many bridges down and many roads blocked. He was uneasily aware that his only reserve was 24 Squadron, which was not at full strength and that this was ten hours away from the scene. It also seemed that there might be a sizeable stores problem as well as a need for as much plant as could be deployed. He therefore gave immediate orders for the whole of 24 Squadron to move to Warminster as soon as possible, with the task of being prepared to carry out flood relief as required. OC 61 Support Squadron was ordered to move himself, Tac Squadron HQ, and Plant and Stores Troops to Taunton as soon as possible to provide support to the regiment. Tac RHQ was also ordered to move to Taunton as soon as possible.

The BM 12 Engineer Brigade was informed of these steps, and the CO's flight was confirmed. It was to be a Beaver from Rochester to Bristol and then by car to Pensford to meet Commander 12 Engineer Brigade at 1300 hrs.

On approaching Bristol the CO took the opportunity of flying over Pensford bridge and its environs. By the time he reached Pensford by car he had quite a different picture of the floods from that which he had formed at Maidstone. There was plenty of evidence of the aftermath of flooding. Low-lying roads were covered in mud and some landslides had occurred. Many bridges had been damaged or washed away. Only three however were on important trunk roads. The village of Pensford was extensively damaged and parts of Keynsham, 5 miles away, were still under water. But in general all the rivers and streams were back to about their normal size.

In short, flood relief in the form of rescue and sandbagging operations was not necessary. Nor was there any need for life jackets or safety boats for those bridging. It began to look as though 24 Squadron and 61 Field Support Squadron might have moved a long way for very little! In fact this quickly turned out not to be the case. Whilst the CO was in the air, 24 Squadron had been diverted from Warminster to Honiton with the task of building a bridge on the A303 at Marsh. And although Stores and Plant Troops were never fully stretched, there was work for them too.

Commander 12 Engineering Brigade and the CO spent some time at Pensford discussing the design of the bridge with OC 60 Squadron—more of this later. The Commander also informed the CO that a fourth bridge was required on the A4 at Keynsham 5 miles downstream from Pensford. This was at a lower priority than the other three bridges and it was decided that 60 Squadron would be given this task after they had completed the Pensford bridge and had rested. (In the event they went straight on to Keynsham with barely a pause.) The Commander and CO then went by helicopter to look at Keynsham, then to 24 Squadron's site at Marsh, which seemed suitable for a HGB, and finally on to Fenny Bridges to see 20 Squadron. They had made excellent progress and were nearing the completion of the launching nose of their Bailey. The Commander and the CO then returned to HQ South West District operations room at Taunton.

The ops room was organized as follows. A "G" Cell under the GSO I South West District, responsible for overall control and co-ordination. This included an officer responsible for helicopter tasking. (Two Sioux from the QRIH Recce flight were permanently allotted for the operation.) An RCT cell responsible for ordering and controlling transport. A "Q" cell. And of course an engineer cell. All this was set up in the District conference room which was large enough and had an adequate number of telephones.

It had been decided to "co-locate" RHQ 36 Engineer Regiment with HQ 12 Engineer Brigade which had until then been in direct command. This had numerous advantages and certainly from the regimental point of view, worked well. There were times, however, when the distinction between the two Headquarters became blurred, particularly when one duty watch officer was covering both. In these circumstances confusion could be caused unless the duty officer is most careful to ensure that all important information and action taken are passed to a responsible officer in each HQ at the earliest possible moment. In theory the log sheet should be enough. In practice it quite definitely is NOT. It may have been taken away for typing; or the Commander, BM, CO, or IO, may be heavily involved from the moment he returns to the ops room. Verbal briefing is essential.

As soon as the CO had been shown round the ops room, Commander 12 Engineer Brigade laid down that he and his staff would continue to be entirely responsible for all dealings with civilian authorities and HQ South West District, thus leaving the CO free to command his regiment.

It was now about 1830 hrs on Friday 12 July. Tac RHQ arrived shortly after this time and was soon set up alongside HQ 12 Engineers Brigade in the ops room. The normal regimental command net was established but was not in fact much used because of excellent telephone communications with squadron HQs. Squadron nets on the other hand were kept busy.

At 1900 hrs the CO spoke on the telephone to OC 60 Squadron and then to OC 20 Squadron. At Pensford setting out was complete and work on the grillages was under way. The remainder of 60 Squadron had arrived and was harboured in two barns nearby. Work was to continue throughout the night.

At Fenny Bridges, 20 Squadron were making good progress. They had been briefly held up for bridging which had been delayed in traffic jams. This hold-up was seized by the OC as an opportunity to change shifts so little time had been lost. Again work was to continue throughout the night.

A warning order for 24 Squadron was left with OC 20 Squadron. It gave the task and likely timings and arranged an RV between the OC, the CO and a local authority engineer on the site at Marsh for the next morning.

With two bridges now under way and two more planned it is perhaps appropriate to consider a number of problems which arose in connection with the selection and design of the bridges. The first and most fundamental of these is the difficulty of deciding what load class of bridge is needed. The requirement will be stated by the local authority engineer responsible for bridges, and will be in the form of a "standard train". It is of course not too difficult to convert this information into a military load classification—it is not too easy either! There is no simple conversion table in the normal bridging pamphlets. Moreover, neither the Bailey nor HGB pamphlet gives details of any load class other than Cl 50 and Cl 80. Thus for a given span, the type of construction for Cl 50 and Cl 80 is available at a glance but any other class has to be worked out.

The Ministry of Transport has classified all roads in terms of the maximum load permitted to use them. It has produced standard design criteria for bridges for each class of road. It is suggested that there is a need for a table in bridging pamphlets giving construction details for each of the MOT criteria for spans between say, 50-250 feet. It would also be useful if the existing tables showed load classes of, say, 30, 40, 60 and 70 as the old Standard Bailey pamphlet did. In the event the type of construction was worked out and then checked with MEXE, who produced a remarkably quick answer long after close of normal play on the Friday evening.

The question of whether to build on the centre line of the destroyed or damaged bridge will not often arise. Speed is of the essence and the time and effort required to build approach roads will normally rule out anything except construction on the old bridge centre line. But this produces a problem with the ramps. Civilian bridges normally carry a number of services—water and gas mains, and electricity, telephone and cablegram cables. Some, if not all, of these will be buried under the road, or to the side of it. It will not therefore be possible to dig in the bank seats to produce level ramps. And the slope of the normal military ramps will not be acceptable for civilian traffic. Arrangements must therefore be made to build a ramp with a suitable slope, by placing fill on the existing road surface, rolling it and then covering it with black-top. The amount of fill required may be considerable as approach roads often slope up to bridges.

At Pensford and Keynsham military ramps were dispensed with and fill was placed right up to improvised end dams at the end of the bridge proper. The end dams at Pensford were of timber; those at Keynsham were made by stacking two nose cross girders one on top of the other. At Fenny Bridges and Marsh military ramps were used but the ends were packed up well above the road surface and fill placed up to the end of the ramps. It will be interesting to see how these approaches stand up to use.

It is also perhaps worth mentioning that Bailey bridges must always have a wearing surface. Timber and nails for this must be ordered and arrangements made to cut the timber to suitable lengths. Finally, Bailey footwalks need to be filled in and screened on both sides with chicken wire or chain link fencing if they are to be used by civilians.

Turning now, briefly to the activities of each Squadron—20 Squadron's bridge was a 120-ft Triple Double EWBB of approximate class 70. Bailey was selected because the necessary width for a HGB could only have been produced by excavating. This was ruled out for the reasons given above. There was a second hold up due to lack of panels—caught in traffic jams. It was therefore decided to launch the bridge and double up in situ, despite the fact that doubling up had already started at one end. This made the eventual doubling up more difficult but undoubtably saved time. At 0700 hrs on Saturday, 13 July, it was discovered that twenty-four panel pins were missing. Despite appalling weather, a helicopter was dispatched to Wyke Regis and the pins were delivered to site before a hold-up occurred. The bridge was finished by 0930 hrs and the ramps were completed by the local authority at 1530 hrs. The local authority also undertook to put on the wearing surface.

24 Squadrons site was best suited to a HGB and the final design was 87 ft 6 in SS reinforced class 80. There were however two complications. Firstly the reinforced concrete arch of the existing bridge had only partially failed. It was considered that any further flooding would cause a complete collapse and perhaps block the stream with consequent serious erosion of the abutments. The local authority therefore demolished and cleared this arch before construction began. Setting out and preparation of grillages, of course, continued while the local authority were working. Secondly the bridge site was in the middle of an "S" bend which meant that the launching site was restricted. This was overcome by careful siting of ghost rollers and even more careful use of counterweights during launching. Because of the comparatively leisured start of work, it was possible to reload the bridge tactically and the squadron produced a copy-book build. Work on the bridge proper, started at 0400 hrs on Sunday 14 July. The bridge was completed by 1530 hrs and the ramps were finished and tarmaced by 2030 hrs.

60 Squadron's bridge at Pensford was 110 ft DD EWBB of approximate class 50. Bailey was selected because it is narrower than HGB and the local authority asked for as much room as possible on the upstream side to enable them to rebuild a permanent bridge in two halves. Work on the bridge proper started at 0100 hrs on Saturday 13 July and the bridge was complete by 1900 hrs. Work had been held up at intervals because of shortage of panels—again caught in traffic jams. Doubling up was seriously held up by the failure of three out of the four ratchet type chord jacks.

These are *not* satisfactory. Arrangements to fly the diamond type jacks from Fenny Bridges to Pensford came to nothing because no helicopter was available. Asphalting the long ramps did not take place until the next day, Sunday, as the only asphalting plant available was deployed by the local authority on urgent road repairs. A wearing surface was put on by the Squadron during the night.

Late in the afternoon of Saturday, 13 July, orders had come through that the Keynsham bridge was now urgently required. As soon as the back of the work at Pensford was broken, a recce party under the OC set out for the site, and working parties were thinned out so that men could be rested before starting work at Keynsham.

At Keynsham, the site was eminently suitable for a HGB. A 150-ft DS reinforced HGB of approximately class 50 was decided on. There was a minor problem of clearance over a telegraph pole lying horizontally across the gap from which were suspended a number of GPO cables. This was resolved by the GPO who built a tubular scaffolding support from the river bed. Work on the grillages started at 0730 hrs on Sunday 14 July, and the laborious task of reinforcing the panels began shortly after. The bridge proper was complete by 1800 hrs and the ramp was finished by 2030 hrs.

As each bridge was completed a small maintenance party was left until the bridge was formally handed over to the local authority. A short description of necessary maintenance tasks was handed over with each bridge.

Load and speed limit signs were erected by the local authority and modest signs were subsequently added by each squadron.

A number of further points are worthy of mention. First—of course—the Regiment had the most tremendous support. None of the hideous problems connected with ordering up bridging and bridging transport and ensuring its arrival at the right time and place ever troubled the Regiment. All this was done by HQ 12 Engineering Brigade. The police—now mentioned for the first time—worked continuously throughout the emergency. They were on the scene before the Regiment arrived and were still there when it left. Their communications, particularly at Pensford, were invaluable, as was their local knowledge. But for them, the bridging could never have arrived in time. Their unflagging efforts in the form of finding and escorting bridging vehicles prevented any serious hold up. The local authority engineers and workmen worked valiantly. Without timely decisions and the provision of men and materials for the ramps, the bridges could not have been open to traffic anything like as soon as they were. The tremendous helpfulness shown by I RWF at Honiton, HQ SW District at Taunton and the School of Infantry Warminster, relieved the Regiment of a great administrative load. Finally without the helicopters of the QRIH Recce Flight, control of the operation would have been immeasurably more difficult.

Second—it must be obvious that this operation was quite untypical of "normal" flood relief work. It was merely a bridging operation.

Third—it was totally unexpected; as all such operations surely will be. No one in Maidstone was thinking of floods in the West Country in July.

Fourth—like the demolition of Sunk Head Fort, the other recent occasion when 36 Engineer Regiment was called upon to operate at short notice in the public eye it demanded a high degree of professionalism in a field which the operational role of the Regiment tended to put at low priority. Large scale demolitions and equipment bridging tend to be regarded as BAOR skills. The lessons surely is that all Engineer units must be really professional at deployment drills, including the setting up of HQs and the establishment of communications, and at all the basic combat engineer tasks. All these must be practised, whatever the cost.

Fifth—arising out of the point above, the regiment was fortunate in having two excellent QMSIs and a number of senior NCOs who had Bailey experience. With hindsight it is clear that Bailey training should still be included in Combat Engineer courses and regimental training. The Regiment had done no formal Bailey training, although it had been very briefly covered in the regimental Combat Engineer B II/B III Course. The Regiment was perhaps lucky to have got away with this omission.

Sixth—the accurate assessment of ETC is as important in this type of operation as in war. The police, the local authority, the local inhabitants, the AA, the BBC, the bus company, as well as the military commander, all want to know when the bridge will be open.

Seventh—the operation proved that the centralized system works well. Between leaving Maidstone and returning, only one vehicle, a Land Rover which blew a gasket, broke down. No piece of plant went off the road or became unserviceable.

Eighth—although HQ 12 Engineer Brigade dealt with the local authorities on policy matters, the CO, squadron commanders and troop commanders had much to do with their civilian counterparts from the local authorities, the GPO, the Electricity Board and so on. It is a great help if sapper officers—and senior NCOs—understand how these various bodies are organized. (It is assumed that the police organization is well known.) More could perhaps be done to improve this knowledge. The reverse is probably true, but passing knowledge of the Services in general, and the Sappers in particular, to these bodies is perhaps more difficult.

Ninth—arising out of the point above—it must be appreciated that local authorities are not geared to react quickly. This is not meant to imply that they sit down and do nothing in an emergency; on the contrary. But such things are overtime rates and the provision of extra money for materials inhibit the immediate switch to 24 hour working that is so easy in the Services. As was said at the beginning, none of these points is new or earthshaking. The fact remains, however, that during this very short operation they were brought home to many members of 36 Regiment with renewed force.

In conclusion it is re-emphasized that this article has been an attempt to describe the activities of one regiment during one rather untypical operation in aid of the civil community. It is the regimental picture only. Since it is unusual for a complete regiment to be deployed on this sort of operation a fair amount of detail has been given. It is hoped that it has been of some interest—the actual operation was the greatest fun.

Photo 1. 120 ft Triple Double EWBB Class 70 built by 20 Field Squadron RE at Fenny Bridges.

Op Giraffe 1

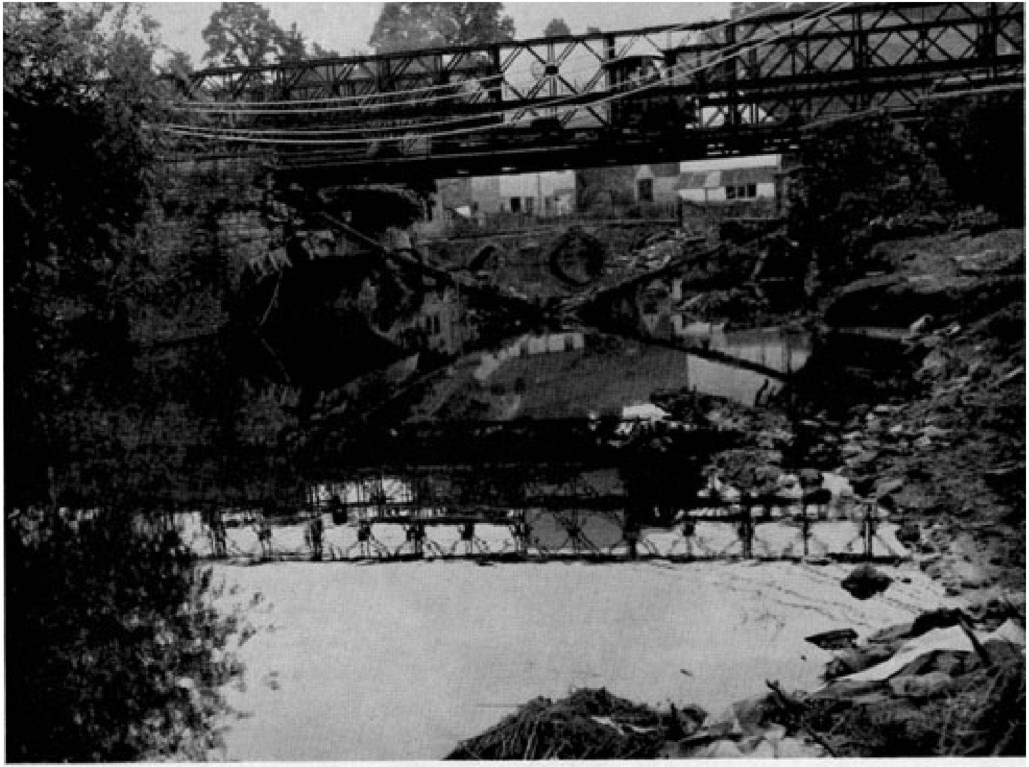


Photo 2. 110 ft DD EWBB Class 50 built by 60 Field Squadron RE at Pensford.

Op Giraffe 2

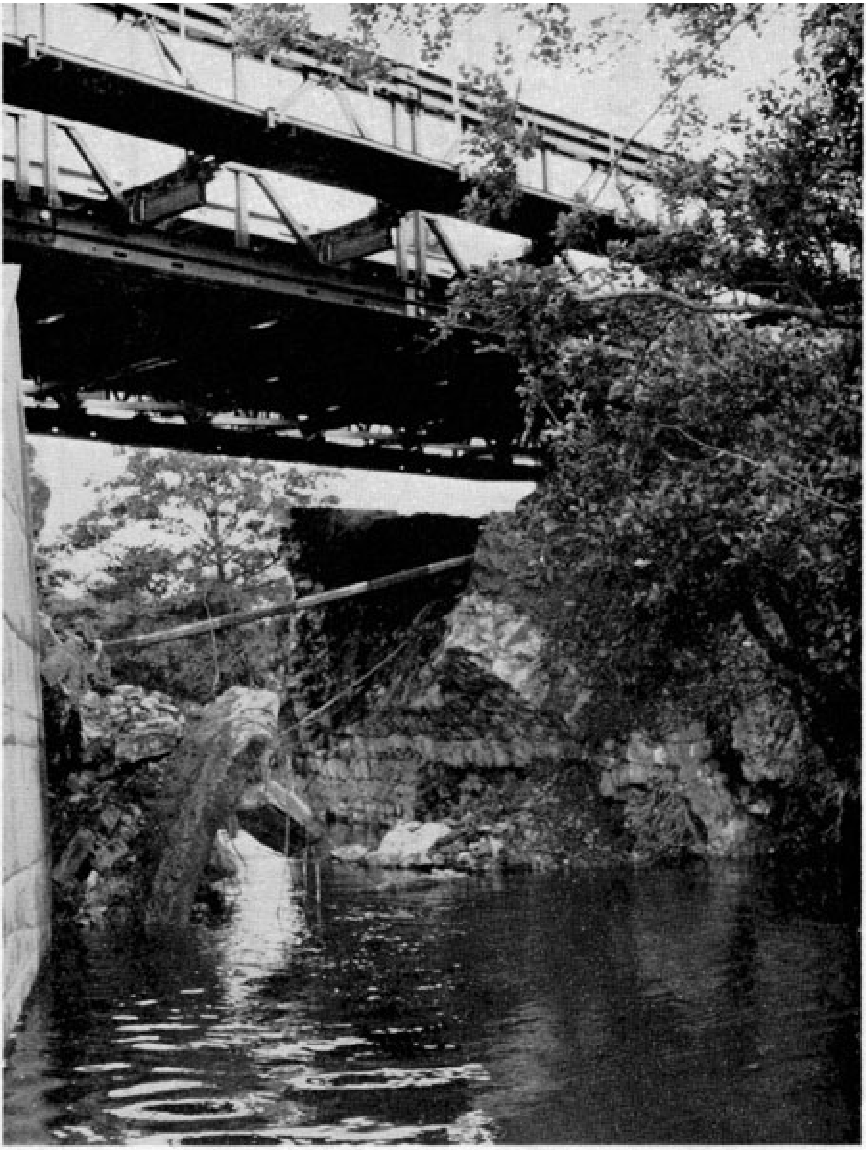
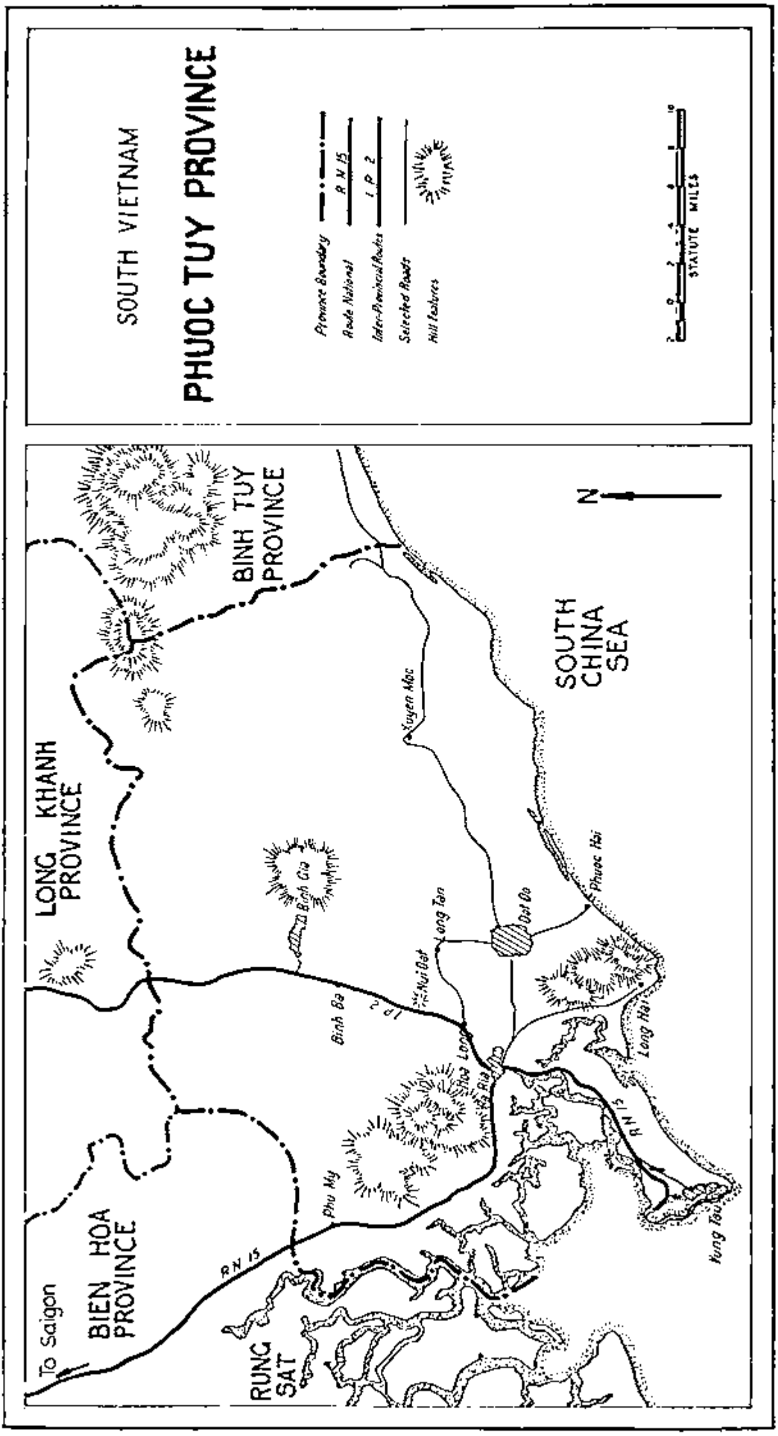


Photo 3. 87 ft 6 in SS reinforced HGB Class 80 built by 24 Field Squadron RE at Marsh.

Op Giraffe 3


SOUTH VIETNAM
PHUOC TUY PROVINCE
Province Boundary
Route National
R N 15
Inter-Provincial Routes
I P 2
Selected Roads
Hill Features
STATUTE MILES
LONG KHANH PROVINCE
BINH TUY PROVINCE
BIEN HOA PROVINCE
RUNG SAT
To Saigon
SOUTH CHINA SEA
N
RN 15
Phu My
Binh Ba
IP 2
Binh Gia
Nui Dat
Long Tan
Xuyen Moc
Dat Do
Phuoc Hai
Long Hai
Ba Ria
Hoa Long
Vung Tau

Royal Australian Engineers in Vietnam

The article was written by MAJOR W. W. LENNON, Royal Australian Engineers. Major Lennon served in Vietnam during 1966 and 1967 where he commanded initially 1 Field Squadron and later 17 Construction Squadron, RAE.

INTRODUCTION

IN MAY 1965, Australia, at the request of the government of South Vietnam, dispatched an infantry battalion to join US forces at Bien Hoa. A composite Australian Logistic Support Company was included with the battalion and this contained one officer and twenty other ranks from RAE. In September of the same year 3 Field Troop of I Field Squadron (RAE) and other supporting elements joined the battalion. In April/May 1966, the Australian force was increased to a two-battalion task force with supporting arms and a logistic support group. The task force included the remainder of 1 Field Squadron RAE (restricted by a field troop) with 21 Engineer Support Troop RAE and 1 Field Squadron Workshop RAEME, under command. The Logistic Support Group contained 17 Construction Squadron RAE (restricted by one construction troop) with 17 Construction Squadron Workshop RAEME under command, and a small detachment of 55 Advanced Engineer Stores Squadron RAE. On Headquarters, Australian Force Vietnam (AFV) there was a SORE 2 (known locally as the Force Engineer) and a very small RAE staff of five all ranks. A detachment of 11 Movement Control Group was also included in HQ (AFV) and the RAE Landing Ship Medium (LSM) A.V. 1355 "Vernon Sturdee" provided assistance with movement of men and material. Soon after the arrival of the Task Force, a detachment of 30 Terminal Squadron (RAE) arrived in the Logistic Support Group. After initial deployment, the total RAE strength in South Vietnam was about 440 while the total Australian Army strength was 4,300.

EARLY TASK FORCE BASE DEVELOPMENT

The First Australian Task Force (1 ATF) assembled in Vung Tau Peninsular (Cap Saint Jacques) for acclimatization prior to moving into their Tactical Area of Responsibility (TAOR) about 30 km North on Route 2, in the province of Phuoc Tuy. The area chosen for occupation was cleared during Operation Hardihood by the US 173 Airborne Brigade assisted by an Australian infantry battalion.

The first tasks confronting the sappers were the location of a suitable water supply and the construction of a water point, and the construction of an off-road hardstanding to permit transhipment of stores and supplies from second line transport convoys to unit vehicles. This hardstand was required for two reasons:

(*a*) Rapid turn around of convoys was required to facilitate the initial build up.

(*b*) With the wet monsoon season imminent, and no roads and tracks in existence in the task force base area, it was considered preferable to limit transport movements within the base to light vehicles which were directed cross country on routes away from proposed road alignments.

An existing well was located within the base area, 40 ft deep and 13 ft in diameter. This well gave a yield of 5,600 gallons per hour which more than adequately satisfied the needs of the task force in the initial period. A Patterson trailer was used initially for purification of the water which registered a very low coli-count after one or two days drawing. A 10,000 gallon collapsible fabric tank was used for storage (and subsequently for fixed-dose hand chlorination) and water was pumped through POL hand guns and an overhead standpipe to provide fast delivery. Most water was transported in the early stages by means of plastic jerry-cans in Landrovers and trailers, since tankers were initially in short supply. Quick delivery was necessary to minimize traffic congestion at the water point.

The task force area included a 200 foot high volcanic vent called Nui Dat. Surrounding this hill was typical red basaltic soil with laterite of varying quality occurring adjacent to water courses. Two small perennial streams originated on the slopes of Nui Dat, one flowing to the South East and the other to the West. Seventy per cent of the area was rubber plantations and the remainder was either banana plantation or grass covered. A laterite pit was established immediately and this material proved to be ideal for initial road construction. In addition a quarry was established on the slopes of Nui Dat, from which blast rock was won. When the wet season started, this rock permitted construction to continue except while rain was actually falling.

The task force base master plan was established early, with engineer advice, and roads and drainage given high priority. Construction of basic accommodation—ablutions, latrines and food preparation rooms—and field defences was commenced, using all-arms labour and engineer supervision and assisance. Since operations were virtually continuous from the time the task force arrived at Nui Dat, and the field squadron had to provide combat support as a first priority, some additional engineer effort had to be provided. One of the construction troops from 17 Construction Squadron (located within the Logistic Support Group at Vung Tau) was placed under command of 1 Field Squadron in August 1966. Their main tasks were the pouring of concrete slabs for Scale A structures and prefabricated buildings, and augmentation to the field squadron in assisting and supervising unit labour on self-help tasks. Sand had to be carried 30 km from Vung Tau for concreting, as did aggregate initially.

In the first month, a 25 ton per hour mobile crushing plant was installed in the rock quarry and this machine provided aggregate for concrete in limited quantities and sizes. Initially the quality of the rock was such that, when wet, it was difficult to feed through the crusher. However at lower levels the rock was cleaner and harder and presented no difficulties.

Unit self-help tasks continued whenever troops were not involved on operations. At an early stage, priority was given to the provision and delivery of a limited number of prefabricated galvanized iron and aluminium buildings 60 feet by 20 feet, for company mess halls-cum-recreation rooms and for headquarters. These too were erected by unit labour. After the first three months, Scale "A"[1] construction was well advanced and planning was going on for Scale 'B' and limited Scale "C" construction.

Apart from conventional aid in establishing field defences, engineers installed various improvised explosive and inflamable devices for perimeter protection. Clearance of fields of fire and approaches constituted an extensive task for dozers.

After several helicopter pads had been built and the basic drainage and road network had been established, some engineer plant was directed on a low priority to clearing the site for an SRT airfield. Construction of this airfield was completed by December 1966 when it was opened to fully operational SRT standard and satisfactory for MRT aircraft in good conditions. The runway was 3,100 feet long (including over-runs) by 150 feet wide with a total longitudinal fall of 50 ft. This fall, in conjunction with predictable winds and the general configuration of the country led to a procedure whereby aircraft take off down hill and land up hill, regardless of wind direction (up to 25 knots). Runway pavement was well compacted, high quality laterite, covered initially with "Peneprime" a commercial petroleum product dust suppressant and road oil. The runway was later fully water-proofed with a bituminous emulsion seal. Parking areas and other installations were progressively added, and extension of the airfield to 4,100 feet was started in early 1968 to upgrade the runway to fully operational MRT standard.

[1] Scale 'A' provides for semi-permanent buildings for food preparation, ablutions, and latrines. Other accommodation is in tents.

Scale 'B' provides semi-permanent messes, Q stores, administration, buildings and canteens.

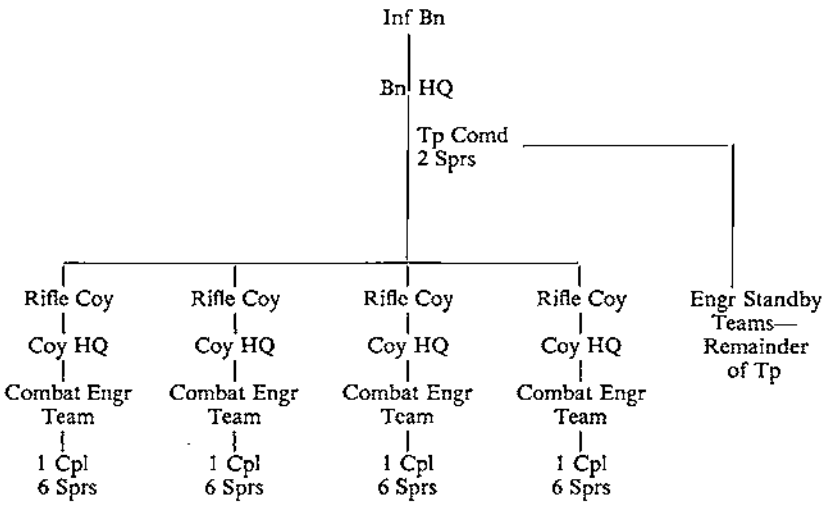
Scale 'C' allows for construction of sleeping huts and other necessary semi-permanent construction.

ENGINEER COMBAT SUPPORT

Since 1 ATF originally contained only two infantry battalions, most operations were of battalion or battalion plus size. The main types of operations undertaken were:

(*a*) Patrolling and ambushing within the TAOR
(*b*) Cordon and search
(*c*) Search and destroy
(*d*) Clearing and securing of routes.

In all such operations there is always a high probabliity that booby traps and mines will be encountered and that Vietcong (VC) hides and caches of food, medical supplies, arms or munitions might be found. Blind artillery shells and aerial bombs are often found and these are normally destroyed to prevent the enemy from using them in improvised mines. Movement is often difficult, slow, and dangerous for small parties. Difficulty of movement can often be overcome by means of helicopters or armoured personnel carriers, but these are not always readily available. Mobility restrictions created a need to provide engineers in small numbers, dispersed throughout the battalion, so that they are immediately available to deal with minor engineer tasks quickly. Although this technique appears to cut across the principle of concentration of engineer effort, dispersion of sappers does in fact give adequate concentration where it is required and when it is required. In most operations a reserve of engineer effort is maintained on standby, on short notice to move, in the Task Force base. If a large task is encountered the standby force is flown into the work area, or moved by vehicle or APC, depending on the urgency and the enemy threat. Firm affiliations have developed between the infantry battalions and the engineer troops who usually support them. Although the engineer support required for each operation is assessed on its own merits, a recurring pattern of employment has developed. For a conventional "search and destroy" operation a battalion will probably have about half of its affiliated field troop deployed with the rifle companies. A typical deployment might be:



The troop commander, or possibly the troop officer, advises the battalion commander on engineer matters and controls the activities of his engineer teams by radio or by personal visits to the companies. If necessary the battalion commander will often make available a Sioux helicopter to assist the troop commander to visit his teams. Sometimes the combat engineer teams may be split even further to give two sappers to each platoon and the NCO to the company commander as his adviser. This sort of situation would normally only occur for short periods in very difficult country, or where extensive mines or booby traps are encountered in a number of locations. Depending on distance, availability of aircraft, and other tasks, the engineer reserve will move with battalion headquarters or be on standby in the task force area. This reserve may comprise the balance of the troop or even more if necessary. Each combat engineer team is usually about half of a field section, the other half being on standby.

Flexibility is the keyword in engineer deployment in this theatre. In some cases engineer combat support may be as small as two sappers with a mine detector proving suspect lengths of road for APC's and vehicles. In other circumstances, engineers become the main force with protective elements of infantry and armour supporting the operation. Such a situation arises when extensive enemy installations are located and have to be destroyed, or when large tracts of land have to be cleared by engineer clearing teams. In any case, the engineer organization must be carefully designed to meet the requirement.

In single battalion operations, supported by a troop or less of engineers, the method of command and maintenance of the sappers must be tailored to suit the situation. It often happens, however, that the area of operation is beyond range of the field squadron radios (AN/PRC 25 and A510 sets) and it is only possible to provide rebroadcast facilities between task force and battalion, no link being available for an engineer net. This then means that the squadron commander must use the infantry nets to maintain contact with his sappers and often finds it necessary to minimize his radio traffic. The effect of this is to place heavier responsibility on the troop commander who is with the battalion. Also, to ensure quick and reliable response, all operational demands (OPDEMS) for engineer material or equipment, are passed through the battalion administrative channels. Although engineers may provide and prepare the items, and even load the items onto helicopters in the squadron area, the normal channel of demanding is through the battalion. If the squadron can monitor the net, preparatory action can be taken as soon as the need is known. The squadron commander, will normally visit the battalion and his engineer troop as frequently as possible, consistent with his other duties. By maintaining close contact with the operation, he can be prepared to change the engineer deployment or strength, if necessary, to suit changing circumstances. Movement of any supporting arms commander to visit his troops on an operation, is usually regarded as a fairly high priority task for available helicopters, though the visit may often be tied in with an aerial resupply.

Although many of the engineer tasks encountered in Vietnam have been of a routine nature, some have presented new problems, and required the development of new techniques. Two of the more noteworthy activities have been tunnel searching and destruction, and operational land clearing.

On almost all operations in Phuoc Tuy, tunnels or underground caches and hides have to be searched. It is normal in most of the villages for each house to have an escape tunnel leading outside to a bunker or air-raid shelter. In most cases, these are innocent and are constructed for self defence, but sometimes they lead into large tunnel complexes. These tunnels and underground hides are used to conceal food, weapons, medical supplies and ammunition. They sometimes encompass complete underground installations, such as hospitals and headquarters. Some tunnels are built apparently purely for tactical purposes, leading to or from a prepared ambush site or killing ground. The largest single complex discovered by 1 Field Squadron was probably on Operation Enoggera where one major tunnel was 1000 meters long and as high as five feet for a great part of its length. In addition there were numerous smaller tunnels, apart from domestic bunkers and escape tunnels. Australian army policy is to search tunnels prior to destruction or neutralization. Experience has shown that intelligence recovered from tunnels and caves is of great value, and worth the risk and effort involved in searching the tunnel. Over short lengths, this is done by the combat engineer teams who move with the infantry. If a complex is struck which is beyond their capacity, reserve engineers will be moved in to assist. When an area is known to be heavily tunnelled, an ad hoc organization may have to be set up to search and destroy them.

Various experimental devices have been used in tunnel warfare, ranging from smoke blowers for detecting entrances and airvents, to special communication devices and rescue apparatus. Special tunnel destruction techniques have been investigated, but the use of 50lb boxes of TNT placed throughout the length of the tunnel has proven to be effective, relatively fast, and safe. Consideration of the economics of weight and cost of explosives are secondary to the time and effort saved in underground work by using well spaced full boxes.

In the hills of Phuoc Tuy province, the VC use natural caves extensively to gain protection from artillery and airstrike. On several operations, Australian sappers in searching caves, have discovered camps for units of strengths up to battalion size. Some of these are so extensive and have so many entrances and exits, that destruction is almost impossible.

A technique which has gained favour in Vietnam with American units is the extensive clearing of vegetation in enemy territory, using earth-moving equipment rather than defoliation. This is done to open up otherwise impenetrable country, (particularly to tanks and APCs), to provide cleared boundaries for future search or cordon operations, to uncover VC installations, and to provide cleared areas on the edges of roads to minimize ambush danger. Australian sappers have adopted this technique, sometimes working with US engineers. Special angled tree cutting blades (known locally as "Rome ploughs") have proven to be useful for scrub clearing large areas. In other types of country, a large chain is used between two size 6 tractors (Caterpillar D8s) with considerable success. Provision has been made for the formation of an Australian land clearing team which comprises tractors and other equipment. The team is useful for other tasks such as clearing sites for village resettlement operations organized by the Australian Civil Affairs Unit.

Anti-personnel mines and booby traps have claimed a large number of Australian casualties in Vietnam. The term "booby trap" is often loosely used. Many of the "booby traps" encountered in SVN are in fact anti-personnel mines. They are often of local manufacture, or improvised by adapting other munitions. In addition, they are often laid in random pattern or in isolated positions. There have been some encounters with booby traps in classical forms eg VC flags and other attractive items prepared to "trap the unwary". Rice caches are often booby trapped. Most booby traps encountered by Australians in Phuoc Tuy province have been explosive devices, though some panjiis and other novelties have been discovered. In the earliest stages of operations, there was a preponderance of improvised devices, manufactured from blind shells and bombs, commercial explosives, and some old French munitions. There have since been increasing numbers of Chicom, locally made, and North Vietnamese grenades, mines and explosives. There has also been an increase in the number of allied grenades and mines which have fallen into VC hands. VC booby traps are used extensively on and adjacent to tracks and trails, particularly covering approaches to caches of material and access tracks to hides. The VC often set booby traps to protect caches and extensively use dummy traps. Tunnels, caves, and buildings will often contain wires which appear to be trip wires but often do not prove to be so. Trip wire and friction ignition grenades are commonly encountered. Various VC techniques for marking mines have been encountered, and these are often sited so they can be seen only from the enemy side—particularly on tracks. The marking methods usually rely on broken tree branches, tied clumps of grass, bound saplings, or patterns of stones. Few conventional anti-tank mines have been encountered apart from one or two old French mines and some VC shaped charges. The VC appear to favour the use of rocket attacks against tanks and APCs in Phuoc Tuy province rather than anti-tank mines.

A large number of artillery shells and aerial bombs have been located on roads and tracks, however, fitted with improvised firing mechanisms. Some of these have proven to be capable of inflicting substantial damage on a vehicle or an APC.

Owing to the prevalence of mines and booby traps in the region detailed instruction is provided to all arms in recognition of these devices, and to sappers and assault pioneers in locating and neutralizing them. Infantry forward scouts have shown that training and practice pay off in this respect.

In addition to countermine activities, Australian sappers have laid several thousand anti-personnel mines ranging from protective fields in the task Force base and nuisance mines in the abutments of vulnerable bridges to a 10 KM barrier minefield designed to shield a village from the incursions of VC. The majority of the mines used are US M16 bounding mines. These were selected for their availability, their suitability for paddy-field subject to partial inundation, and their lethal radius and adaptability to trip wires and anti lift devices.

FIRST AUSTRALIAN LOGISTIC SUPPORT GROUP

The First Australian Logistic Support Group (1 ALSG) was established in Vung Tau peninsular, about 30 km South of 1 ATF. It was allocated an area of sand-dunes and low scrub adjacent to the beach on the eastern side of the peninsular. Although an MRT airfield and various other facilities were available in Vung Tau, the Australian area was completely undeveloped except for one poor quality bituminized road cutting through the dunes. The area, known as Back Beach, was used as a staging area for the task force prior to their move north. This led to considerable overcrowding for a short period and development of the area was delayed and hindered by the fact that large areas could not be vacated for basic earth works to be done. In order to permit best use of the area it was decided to establish the base on two levels. The sand hills, in some cases as high as 60 to 70 feet were to be cut and spread to a level of 30 feet. This provided sufficient fill to reclaim extensive swampy ground and allow establishing work areas a few feet above sea level. Generally the plateaux were to be used for accommodation and office areas, and the lower level was for hardstandings, storage areas, workshops and vehicle parks. A suitable drainage plan was incorporated in the earthworks design. 17 Construction Squadron (restricted by one construction troop) was part of 1 ALSG at this time and was charged with constructing the logistic base. In August 1966, one of the two Construction troops was detailed to 1 ATF to assist with base development. Soon after this, however, some construction work in the ALSG area was let to local contractors, the work being coordinated and supervised by 17 Construction Squadron. Construction of semi-permanent buildings was delayed for some time while earthworks were in progress, and in several cases it was necessary to build temporary essential facilities in locations which were later to be reshaped by the bulldozers. Dozers worked 24 hours a day on the monotonous task of shifting millions of tons of sand. This work presented some special problems. The sand-blast effect of blowing sand cut out radiator cores on tractors in less than 1000 hours and tracks had to be replaced at about the same time. Motorized scrapers could not traverse the sand when loaded and their employment was limited to on-road movement. Tractor drawn scrapers performed satisfactorily in the sand.

A water point was established at Back Beach by dozing a lake out of the sand in one of the low lying areas about 300 metres from the beach. The pond was enlarged and deepened to about 5 feet in the middle, by means of a dragline excavator. The water was cloudy but not at all brackish, and after coagulation in S-tanks it was chlorinated by hand and delivered under pressure, using petroleum equipment. Handguns and an overhead standpipe were used in conjunction with the delivery pump to provide fast delivery to either tankers or jerrycans. It was thought that the narrow neck of the peninsula probably conformed to the typical island geological configuration with a fresh water lens occurring at sea level. Elsewhere on the peninsula, American engineers were drawing fresh water from shallow wells.

As soon as the earthworks had been completed in any area, traffic bearing ground was clad with blast rock which was provided from US Army quarries. Quarry rock was at a premium, but 1 ALSG was allocated a fair share for development of hardstandings and storage areas. Arrangements were made for much of the repetitive building construction to be undertaken by local contractors. Initially, contracts were let for concrete floor slabs and later for construction of standard design Scale "C" buildings for offices, Q stores and troop accommodation. The majority of these buildings were 65ft × 18ft, with simple trusses on 6ft 6in centres, CGI roofing, and timber or CGI wall sheathing. Top hinged shutters were incorporated in the design to provide suitable ventilation on hot dry days, and protection from driving rain or sand in windy weather. The better contractors, after they had proven their ability, were awarded contracts for more ambitious buildings such as large stores sheds 200ft long by 45 ft clear span. The effort of the construction troops was directed to special construction tasks, supervision of contractors, and providing support to the task force.

In addition, some construction, particularly interior work, had to be done in and around headquarters buildings where security problems could arise if contract labour was used. Such tasks were done by sappers. Initially all prefabricated metal buildings in the ALSG area were built by sappers, but later some of these were done by contract. A number of buildings presented special construction requirements. The field ambulance included an operating theatre, pathology laboratory, and intensive care ward. These rooms contained air conditioners and various other electrical installations. The hospital also had a "Dust-off" helipad constructed adjacent to the operating theatre. Serious casualties were evacuated directly from the field to the hospital by helicopter and were almost invariably on the operating table well within 20 minutes of being hit. A two-storey, steel framed, all-ranks' club was built on the beach with changing rooms, bars and other recreational facilities. This building was designed and partially prefabricated in Australia, the steel being cut, welded and drilled before shipping to Vietnam for on-site assembly and field welding.

The strong and constant winds of the dry monsoon undercut the sand from unprotected structures and have, in some cases, caused partial collapse of concrete slabs and buildings. In addition, dunes are created in the turbulence on leeward sides of structures and often threaten to bury buildings. In traffic areas stabilization was achieved satisfactorily by use of quarry rock. However, since the rock was scarce, it could not be used in non traffic-areas and other methods had to be employed. Banks were stabilized with bituminous emulsion with grass seed sown beneath it. In some places, success was achieved in stabilizing the sand by spreading topsoil which had been stripped from lowlying areas elsewhere on the peninsula. This topsoil contained local grasses which generally took root again, given some rain.

A small detachment of one officer and eight other ranks of 55 Advanced Engineer Stores Squadron was included in 1 ALSG, to coordinate procurement of engineer stores from Australia and from US supply depots, and to hold the theatre pool of engineer construction equipment. This detachment was soon increased, and large stocks of stores were held in the ALSG area. Resupply forward to the task force was by means of daily road convoys, helicopter lifts, and after construction of Luscombe airfield, by SRT aircraft. On several occasions engineer stores and heavy equipment were moved halfway to Nui Dat in LSMs; one of which was operated continuously in the theatre by Royal Australian Engineers. On Route 2, linking 1 ALSG with 1 ATF, there were two French Eiffel bridges limited to Class 12 capacity, and some heavy engineer plant had to be shipped in LSMs or American LCMs to a hardstand north of the bridges. Road transport was used from the hard to Nui Dat. Whenever heavy plant was moved, spare shipping space was used to move additional engineer stores to the task force. In the first 6 months, 5,000 tons of engineer stores were moved forward to the task force by one means or another. A detachment of 30 Terminal Squadron was added to 1 ALSG to assist with unloading stores and material shipped from Australia or procured from American sources. An extensive sealed helipad was built in the ALSG area adjacent to both Ordnance and Engineer stores depots to permit speedy aerial resupply by Chinook and Iroquois aircraft. A detachment of a Movement Control Section operates mainly in Saigon, under HQ Australian Force Vietnam (AFV).

INCREASES IN RAE STRENGTH

At a very early stage it became apparent that a larger RAE force would be necessary to provide the required support. Inadequacies were particularly apparent in engineer stores handling capability, electrical tradesmen for power reticulation and maintenance, supervisors for contract work, and engineer planning staff on HQ AFV. In less than two years from May 66, a number of increases have been authorized and the RAE strength has risen from about 440 to 900 for an overall army increase from 4,300 to 6,600. Currently RAE comprises 13 per cent of the whole army strength in South Vietnam. The Force Engineer is a Lieutenant Colonel with a staff of five officers and nine other ranks. He commands all engineer units except the field squadron and engineer support troop which are under command of the Task Force. A works section coordinates all construction, and has a detachment in the Task Force area responsible for base development planning. A special increment was provided for a limited period to boost the electrical trades capacity in the force to establish power reticulation in each area. The force pool of construction equipment has been greatly increased in range and size of machines and unit establishments have been amended to adapt units to the requirements of the theatre.

Quarrying activities at Nui Dat have been considerably expanded and two rock crushers are in use. It was found that there were few sappers familiar with quarrying operations and there were a number of problems with the equipment, which had not previously been used in sustained production. Consequently the deficiencies in the crushers have been eliminated and renewed interest has been created in training specialists in quarrying and other activities. Similar problems occurred with well-boring. New equipment had not been proven in operation, and there were few sappers with knowledge of the art.

CONCLUSION

The "lessons learned" are too numerous to list here. Most of these lessons are not new—they have merely been revised. Many of the time-honoured teachings of principles of engineer employment have been proven again and again. It has been necessary to adapt the some of these principles to the peculiar circumstances which apply in Vietnam. The practice of breaking the engineer field troop down into groups sometimes smaller than sections may invite criticism; however, this technique provided better control and economy of effort, yet still ensure adequate concentration of engineer effort to accomplish any tasks encountered.

The importance of early deployment of engineers has been emphasized. The need for adequate planning and coordination staff on engineer headquarters has been confirmed. The value of heavy construction equipment soon became apparent, and whilst there were some applications for lightweight, airtransportable plant, the heaviest available equipment was usually preferred for its higher output and efficiency. The enormous tonnages of engineer stores and material required for this type of war is significant.

The advantages of close affiliation between engineers and other arms has been apparent in all operations—and the ability, versatility, courage, and initiative of the Australian sapper of today is widely acclaimed by those who have served with him in Vietnam.

Fig. 1. Entrance to VC tunnel system. The trap-door lid was cast in concrete.

Fig. 2. Task Force area—Field ambulance ward. Galvanized iron and timber structure with insect screening.

Fig. 3. Task Force water point at early development stage. The petroleum handling piping and pumps permitted fast issuing to vehicles.

Fig. 4. Expedient replacement of Bailey Bridge blown by VC. Timber bearers, and partly damaged transoms were used with PSP decking.

Fig. 5. CH 47 "Chinook" lifting Size O tracked tractor for transport to new helipad site.

Fig. 6. 1 ALSG in May 1966 during early stages of arrival. Sparse vegetation exists on sand dunes.

Fig. 7. Galvanized iron prefabricated office building under construction by Sappers. Normal building time forty man days (including concrete).

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Fig. 8. Road alignment prior to arrival of sappers. Trees were cut by unit labour to assist with drying out.

Fig. 9. Size 8 wheeled tractor with three cubic yard multi-purpose bucket—working well in extremely heavy going during wet monsoon.

Airborne in Arabia

MARCH HARE

"ARE YOU staying long in Beirut?" asked the Lebanese lady sitting next to me. I wondered. It was a question very much in the vein of the last ten days, a question that could imaginably have been put to Alice by the Duchess. Except that in this case the questioner was far too attractive to have been the Duchess and I was, happily, sure not to be Alice.

But it had all been rather mysterious and amusing in true Alice style, a freshening and gratifying part still of Army life that places it cuts above the despairing boredom of a nine till five working day. And a welcome change too, to soldiering in Southern England. "Would I like to help an Arab state decide what they could do with a particular type of transport plane that they have?" my Colonel had asked. Certainly I would and the afterthought that this particular type of plane was a bird that rarely migrated to British shores, and one that I had never seen, reduced my keenness not one whit. Some homework, the long expected delay over financial cover and I was away. "Be back inside two weeks" the Colonel said, "we've an open day shortly after." Plenty of time, I thought, but then I had forgotten to aim off for Eastern habits, which encourage the use of a Mad Hatter's watch for recording time in days rather than hours.

Wonderland on this trip began in Beirut. Here the juxtaposition of opposites is so glaring—beauty and shabbiness, pot-holed tracks leading off a spanking new dual carriageway, peasants scratching a ramshackle home under the eaves of the rich themselves. Either one extreme or the other and so it was with my connection on from Beirut for there was not a mere half an hour's delay but a wait of half a day for the plane to take us on: goodness knows what happened to the one that was missing but eventually—no doubt with the help of Allah—a Viscount dropped out of the skies and in we piled. The fuselage bulged with oversize oil men, local travellers and a few wanderers like myself. Before long I smelt a faintly feminine perfume that threatened to stifle the sweaty stench from over long waiting bodies; it was a more agreeable atmosphere certainly that, as it grew, reminded me of the scented places of amusement that can be enjoyed around the Mediterranean. Eventually, in the toilet, I discovered the source. There was no water (they must have forgotten to fill up in Beirut) but instead the largest possible bottle of eau-de-Cologne had been placed on the wash basin. Flows freer than water, I thought, as I sloshed it around my face and hands.

By now all heavily scented, we trooped off into the midnight heated air like a swarm of perfumed ants into an anthill—past Doctor Who-like officials and out the other side. "Our Man" must have given up hope for there was no one to meet me and so—emptiness; perhaps the same sort of feeling that Alice had falling down the well, complete emptiness plunging into the endless depth of the sparkling night sky. A still hot air, the airport building deserted, flickering oil refinery flames in the distance and finally the lights of the town miles away across the desert brought one back to semi-reality. A taxi appeared out of the blackness (by courtesy of Allah) and in we swooped unspeaking to a hotel full of air conditioners and civility for a few hours kip.

Morning and the stillness had gone, in its place the noise of building work, shouting, hooting and the blinding white sunlight provided a morning symphony. "Our Man" had been warned by immigration of my arrival and took me off for a brief "picture putting-in". I went to my permanent accommodation in a mess used by members of a small resident team, enthusiasts who revelled in the pure pleasures of space and sun. An issue of an Arab headdress to replace my red beret ("you wont look so obvious and it'll keep the sun off" I was told) and then I was taken to meet the Chief of Staff and many other local officers. One of them, Ali, was assigned to me—or perhaps it was the other way round for I was due to provide the service and he to be the employer. Altogether the absolute civil reception was free from speed or stress and reflected the stillness and politeness of the desert. There were a few words of welcome, cups of coffee, pauses, and then so carefully spoken by the Chief of Staff —"And what was the weather like when you left?" No idle enquiry for he had spent years in England and had been at Sandhurst when, as I discovered later to my surprise, I already had pips on my shoulder. This background was not exceptional. Although of Bedouin stock, they showed a cosmopolitan touch and had broad experience of the world. The town itself was proof of the modernity of their approach to internal affairs and the wisdom of their spending. The revenues from the oilfields up the road were partly used in social services, building and roads, power stations and airports, so that the standard of living of all must have been comparatively high and the cost of it extremely low. It was an admirable answer to the threat that "wealth corrupts" and a perfect example of the marriage of a modern way of life to the traditional standards of old. The local Chancellor of Exchequer could have no problems at all.

The next day we dug deeper to the root of my visit. They had two ——u's, they said, for the support by air of the Army, but what could they do with them? They also had eight (or so) parachutists trained in England and what could they do with them too? Would it be possible to jump from their ——u's? The Alician influence was growing stronger, for it became clear that I was not expected to advise on pure air transport matters but on the more specialized aspect of parachuting. Yes, they had plenty of parachutes (they said) about a year old and unused, British of course—so they should be all right. Weapon containers too. Hmm, I thought, as I tried to remember what progress, if any, had been made on the standardization of British and American airborne equipment. A *cri-de-coeur* signal home produced no quick answer so Ali and I pressed on to locate the equipment and the parachutists. The bodies were easier to find than the equipment some of which, for no obvious reason, had been separated into obscure hiding places—such as a tank workshop for weapon container ropes.

It was an enjoyable treasure hunt. The modus operandi was to button-hole various staff officers and seize upon any clues to launch a search upon some hitherto unmolested store. Daily Ali and I saw the Chief of Staff at an Eastern version of morning prayers. As a way of conducting business graciously and apparently efficiently it can not be beat but it took time which was comfortably spent in armchairs in a cool shady office. Certainly it was a gentle way of recovering after the night before spent with the Residents and their privileged stock of drink; it was also an admirable spot to cool off after the drive into town through the baking oven heat of the desert. Callers on the Colonel padded reverently into his office, sat and took tea or coffee and joined in the general restrained conversation before sensing an opportunity, or perhaps in some respected order of importance, when they would move silently to the Colonel's side, whisper in his ear and then slide gracefully out. Mission accomplished with the least effort all round.

The Residents thought it a great joke when I told them what my own mission was; "You wont do it in a week", they had said, "the last fellow who come for two weeks stayed six." With an eye to a timely departure and so as to solve my conscience if the parachuting came to naught, I spent a Sunday (whose I forget) writing up an account for my sponsors of the all round capabilities of this marvellous short range transport aircraft in its many roles. The next day I warned the Chief of Staff that I would have to leave in three day's time. At once decisions were made, the Colonel decreed—"the day after tomorrow"—and reflected where we should go to jump. The airfield itself was not popular as all the locals and walking donkeys would swamp in to see the fun. In fact the flatness of the country around made it ideal for air transported operations of all types and one could be sure of a perfectly good DZ by pinpricking a map; there was no need to take account of roads, railways, fences, safety margins and other features that clog parachuting in England. But soon all was decided: spectators (military) there would be, ambulance and wireless and the time was put as early as possible in the day before the breeze sprung up.

Although we have a lot in common with our American friends, we don't use the same parachutes nor the same method of fixing them on the cable in the aircraft. No success of any sort would be possible unless this was sorted out; "Our Man" therefore arranged for the regular fortnightly visiting RAF flight to fly in some strops from the nearest base. They arrived in time and we slid them on to the aircraft cables thus providing a hook onto which the D rings of our static lines would fasten. Semi-success. Consolidation followed. A meagre amount of synthetic training, container packing and parachute fitting was sped through (thank goodness the RAF were not around—they would have blanched at the non-Abingdon drills; I wondered if the eight parachutists were properly trained, perhaps they had spent all their time in England battling it out in P Company or even whooping it up in London). Then—"what about the pilots?" Height, speed, DZ marking, green lights, red lights—it would have been rather nice after all to have had a steady old PJI at hand. Paratrooping with the RAF is all a "piece of cake" a natural chain of events over which one has little, if any, control. But this was too much like hard work to keep parachuting enjoyable.

We dossed down at the airport that night but sleep was not instant. Perhaps it was the lively mattress or the heat, possibly the personal briefing one gives oneself before any important event was more complicated then usual. I worked out the numbers of sticks we could do by landing the plane on the DZ, wondered what the Arabic might be for "Bend your knees more", and thought about the side door of the ——u with its un-British step. It wasn't a large opening anyway and because of this step, we would have to adopt an embryonic shape in the door to get out without falling flat on our faces into thin air. Still the back door would be easier . . . and I slept.

The morning was beautifully cool and still as we trooped out to the friendly looking plane with its tail high in the air. Up and over the town, high over the bay and we gradually descended to parachuting height. Ali and I only were in the first stick from the side door; as my parachute opened I looked back to watch Ali make his exit but I was close to the ground before I saw his shape drop from the aircraft and his canopy glisten in the sun. We marked out a Tee for the pilot to drop the remaining sticks on and clambered aboard again after the aircraft had landed easily on the rock hard sand, (they really did not need paratroops at all unless it were to keep "with it" militarily). The eight parachutists had been to Abingdon, I discovered, for when the green light came on they shot through the door as if the fear of Allah was upon them and, as despatcher, I had nothing to do. Style was mostly absent but they had no mishaps so with confidence established all round we fitted our chutes for the longest stick we could manage (ten) out of the rear door. This was a so much easier exit—like stepping on a banana skin without the bump—that I wondered if the side door was really meant for parachuting. We used up the remaining chutes with one for the Queen (or Allah in their case) from double the height and floated down all over the place. The spectators thought it great fun and so did we—smiles everywhere.

After a drink with the Residents I was away in a larger aircraft dozing over some of the biggest DZ's in creation. Sometimes a track would cross our path and once a pipeline could be seen heading straight as a die the same way. I thought over the happenings since I passed the other way lathered with eau-de-Cologne ten days before and remembered their way of life and working, their sense of space and time and yet their decisiveness and shrewdness in getting exactly what they wanted. Ali was shrewd too, I realized now, for he obviously took time to see the British Major make the first jump before he made his exit!

The chocolate brown peaks of the Lebanese mountains pushing through the carpet of sand were now visible in the distance as the Duchess—I mean Beirutan beauty next to me—said: "Are you staying long in Beirut?" Why not, I thought, a missed flight or two is to be expected out here and, after all, variety is the spice of life—and of the Army, thank goodness!

Computered!

MAJOR G. K. BOOTH, RE, BSc(Eng), CEng, MICE, AMBIM

INTRODUCTION

TWO YEARS ago an article in this Journal (Captain Brodley: December 1966) raised the subject of computers referring to a lack of understanding and progress in the Corps. There has not been a great change in the last two years. In July 1968 the Central Training Council said that top management urgently needs to be taught what computers can do and what training is required for those who operate them.

I will start by saying that I am a computer enthusiast and believe they are one of the keys to the future. In the nineteen seventies the most important industry in the world, after oil and motor vehicles, will be computers and by 1970 computers may well be the biggest single investment expense for major business organizations. Like others in the Corps I have taken advantage of the excellent computer courses run by the Royal Signals and Royal Military College of Science and feel rather frustrated that there is not a Royal Engineer computer to use: it is, of course, possible to hire computer time for certain projects. The title for this article should be "Computed" which rhymes with deputed but unfortunately the title still seems to rhyme with snookered.

The Gunners, the Navy and the Air Force have computers in the field. RAOC and REME have computers and the Royal Signals have advanced to a second machine. Why do we not have a computer? A similar question must be asked at many board meetings. Computers have many proven civilian uses but there are still many business organizations that do not have one. In this respect the Royal Engineers and many civilian business organizations are in a similar position: The question of a computer has been considered generally but one is not yet installed.

The aim of this article is to show how computers can be used and some of the associated problems and finally to suggest the action the Corps should take regarding computers. The following headings are used: Characteristics; What a computer can do; How we could use a computer and What we should do now. This article does not describe: Boolean Algebra; the components and operation of a computer or programming.

Throughout this article the word computer is the normal abbreviation for the electronic stored address digital computer. It should be remembered, however, that the analogue computer is a better and cheaper tool for certain applications and a current trend is the development of hybrid analogue and digital machines.

CHARACTERISTICS

These characteristics are not exhaustive but cover some salient features for potential users.

Computers. Computer development is extremely rapid. First generation computers were slow thermionic valve machines of which very few are still in use. Second generation machines made use of transistors and third generation computers coming in now use semi-conductor integrated micro circuits. These third generation machines are very much smaller, do not require an air conditioned environment and are much faster working. Typical speeds to add or substract are 7 millionths of a second (μ sec) and successive addition gives multiplication or division in 14μ sec. Future speeds will be measured in nano-seconds which are billionths of a second.

Speed is one of the major advantages of a computer. It allows the rapid or real time response of weapon systems. Calculations are now carried out that could not be completed in a life time manually. There can be a rapid interchange of data as used in seat booking systems and in general real time computing means a considerable cut in paper work.

Over the last ten years the cost of computing power has been divided by forty, but today one does expect to use much more computing power.

The computer and peripheral equipment are known as hardware.

Peripheral Equipment. The computer is the heart of the system but one must be able to feed information in, read out and store data. Peripheral equipment is as important as the central processor and probably as expensive: it is also generally the limiting factor on speed of operation and scope of an installation. The following examples illustrate the range of equipment. Computer output can be on punched paper tape or printing with speeds varying from a 15 characters per second teleprinter to a 200 lines per second Xeronic printer or a cathode ray tube display through which the computer can also be interrogated with a light pen. Another example is storage where cost depends on speed of access: as an approximate comparison storage in the central processor has an access time of 1μ sec and costs 1*s* 3*d* per bit whereas a magnetic tape, which takes 36 seconds to traverse and you may have to change tapes, only costs one thousandth of a penny per bit. Core storage requirements must not be underestimated, as they often are, there must be sufficient room for the compiler, a long programme, input data and a working store.

Software. The computer must be told exactly what to do. This is done through the compiler and programmes or software. Software is as important as hardware and computers are being sold today on the success of their software. There are three trends. The first is that anyone should be able to communicate with a computer without using a special language. The present simple languages require large compilers and core storage and developments will mean even more. Secondly it is hoped to "teach" computers so that they will not require such detailed instructions and will operate with flexibility at even greater speeds learning by their experience. Thirdly: although it is expensive to produce, software is included in the cost of the hardware at the moment and the user pays for programmes he may never use. In future it may be unnecessary to pay for anything except the most basic compilers and programmes. Already an independent software manufacturing industry is developing.

Staff. It is a sad thought that although the number of computers in use will probably double in the next three years their capabilities beyond simple applications will not be appreciated by managers and there are not sufficient systems analysts to exploit their full use. The shortage of good computer staff is shown by the advertisements in the national newspapers. The prospect of a brand new computer with stimulating systems problems will attract good staff, but how long will they stay and what does the owner of last year's model do?

The first requirement, probably before a computer is ordered, is systems analysts, then programmers and lastly operators. It would be difficult to fit these specialists into the normal military employment and promotion system. The minimum requirement would seem to be a military man to guide and control the systems analysts. The cost of staffing can be greater than that of the hardware.

In general a computer enables existing staff to cope with an increasing work load or may help overcome staff shortages. Army Pay went over to computers when National Service ended and there was a shortage of Pay Sergeants. New large computers have programmes to sort and organize their work which reduce operating staff.

WHAT DOES A COMPUTER DO?

What the computer can do depends on the peripheral equipment, skills of systems analysts and programmers and to a lesser extent on the actual design of the central processor. Basically, however, the computer can be used in three roles.

Data Processing. Most of the early computers mechanized existing data processing systems in order to carry them out more efficiently and quickly. Files, generally on magnetic tape, are updated by inserting data and periodically information is extracted and processed. Familiar examples are bank statements and electricity bills.

Calculations. The computer is used as a sophisticated slide rule. It is not difficult to write a programme in a high level language like Algol rather than doing a calculation and then the programme can be used repeatedly with different input data. There are libraries of programmes to choose from and it may be necessary to decide which one of several programmes should be used to solve a certain problem. The main requirement is that the input data must be presented in the required form. Should it be necessary to write a new programme use can be made of sub-routines already included in the computers compiler. The computer is ideal for algorithms, step by step calculations, and is encouraging more practical use of linear programming and matrix algebra.

For calculations a computer requires processing power but for data processing processing power is secondary to speed of input and output: large modern installations satisfy both these needs.

Simulation and Forecasting. An analogue computer is used to set up an electrical model of a system to be studied. Examples of systems studied are: vehicle suspensions, guided weapon controls and chemical processes. Voltages represent the various states of the physical system and can be used to control servomechanisms. The time scale which is an essential feature of any system for analogue simulation can be adjusted to suit investigation.

A digital computer was used to simulate daily courses and give the best three for the winner of the 1968 single-handed Trans-Atlantic Yacht Race. A digital computer is also used to speed up the playing of war games at the Defence Operational Analysis Establishment.

Misuse. There are also three ways in which a computer should not be used. First, there is little to be gained from reshuffling data which has already been adjusted over a period of time and has little freedom for alteration. Secondly, it is a waste of time using a computer to achieve "guestimates" by inaccurate working on unreliable data. Thirdly, a computer does not make management decisions, it is not in control. A computer does not optimize variables to produce its own best answer but merely compares accurately and in detail alternative courses of action selected by managers. The computer should mean more decisions on better information, but not complete information, otherwise there would be no need for managers.

HOW COULD WE USE A COMPUTER?

This is the crucial question. Commercially one would expect to increase profits by: reductions in staff and office equipment; increased turnover; stock reductions; quicker billing and better control. Militarily one will make similar savings and save time or work in real time.

The correct use of computer power is a complex problem which is growing more complex as computers become bigger and faster. One aim is always to make computers simpler to use but at the same time another aim is to produce even more sophisticated applications. A systems analyst will determine the need for a computer and establish its correct use. He must be given the problems and the bounds within which to work. If progress is to be made one must accept new systems rather than computerising existing ones.

The present trend in computers is a central processor that will satisfy a variety of users: it can be used equally well by the accounts department or the design office. If a machine is installed that will economically cope with pay or stores and other uses are to be tried out it will rapidly become overworked and have insufficient storage as often happens. A small organization is unlikely to justify a computer for one money earning role but must use it for a number of roles.

The following computer applications are used to illustrate significant points and do not form an exhaustive list.

Intelligence. One of the most important commercial uses of a computer is that it can reduce the bulk data, input and processed at lower levels, to produce and up date top management information. A similar system would be of great value to a commander in battle. The provision of sufficient low level military input in the time frame allowable would seem to be one problem. If this system was introduced it would be on a headquarters staff basis and not peculiar to any arm. Such a system has been considered for BAOR and Royal Engineers were to have been one of the major users. Perhaps now that the emphasis is again on BAOR there will be further developments in this field.

Engineering Calculations. A great variety of software exists to solve problems. The most productive use of a computer is to put in a programme and use it time and time again with different data. Engineering calculations can be computer time consuming if a new programme is needed each time possibly involving changes of high level language and in addition requiring some trial runs.

Existing design staff can become computer programmers. They are then relieved of tedious repetitive calculations of detail and can spend more time on design principles. A cost comparison based on a four span reinforced concrete motorway bridge has shown manual calculation to be almost twice as expensive as that using a computer costing everything except the time saved by the computer calculation which was more than 50 per cent.

It is possible to have a system with a cathode ray tube display on which you designate a span and loading and the computer designs a bridge. The elevation of the bridge is shown on the screen and can be altered if required. Finally the computer prints out detail drawings and stores lists or contract quantities. This system would require a considerable backing store and a considerable demand for bridge designs.

Network Analysis. Network analysis in its simplest applications does not require a computer but as soon as projects become complex, say 120 activities or more, or projects have to be related or resources balanced the work is best done by computer. At the Military Engineering Experimental Establishment eighteen projects are programmed with PERT and this costs approximately £130 a month hiring computer time. Programming alone does not justify a computer but one is soon looking forward to extending the system to include stores ordering, detailed workshops planning and analysing costs.

Stores and Pay. These are already dealt with by centralized computers.

Postings. Posting plans are often affected by external changes. They are a shuffling of data that would seem ideal for a computer. The necessary inhibits could be fed in, a number of alternative plans could be produced, if deemed necessary, and one selected. This would become a general system but perhaps we could initiate it.

Resources. Allocation of resources is essentially a part of programming but it is considered separately to emphasize an important point. Take as a simple example controlling the allocation of plant to projects by computer. Requests for plant and reports on plant availability must be in a suitable format. Instructions from the computer must be issued and acted on. It would be possible to produce a simple streamlined system but if more efficient working is required after the initial improvement due to the system more information must be fed in and more orders issued.

The Universal Aid. Children who build "computers" and learn Boolean Algebra in primary schools today will think no more of a computer than "yesterdays engineers" thought of a slide rule. An organization that is not properly equipped will not attract the staff it requires and in future this will apply equally to engineers and staff officers.

Education. You are unlikely to discover the full use of a computer until you have one. There is a certain amount of truth in the statement that the only benefit from the first computer is to be able properly to use the second one. It has recently been estimated that 70 per cent of companies investing in a medium sized computer nstallation did not cover their costs over five years.

Conclusion. Regrettably from the uses considered a general educational need and a few engineer calculations do not seem to justify a new Royal Engineer computer.

WHAT WE SHOULD DO NOW

Before deciding what we should do, a short review of the computer future is necessary. There are four developments that will affect our use of computers.

(*a*) Central processors will become larger and more powerful. Several government projects under development will require computers whose power is greater than all their computers already installed which is over one hundred. One commercial development is a computer with a central processor programmed to cope with nine users simultaneously and a store sufficient for a total of one hundred users.

(*b*) To enable the large central processors to be used communication systems must be improved. The aim is access through public telephone lines. A proposed police network envisages six hundred remote computer terminals. At the same time there will be improvements in actual communication with computers.

(*c*) There will be improvements in small desk top computers. Today for £2,000, that is five times the price of an electronic calculator, one can buy a desk top computer. It is a small computer the size of a typewriter with a limited store and the human operator partly replacing the electronic control unit. There is a cathode ray tube showing three ten digit registers: working; working accumulator and temporary store. Programmes of up to 196 steps can be typed on magnetic cards using the keyboard which includes qualification and jump instructions. Output by teleprinter and x–y plotter is being developed. This machine has a terrific potential.

(*d*) In general as far as development of computer usage is concerned the automatic data processing phase is now largely complete and we are entering the phase of design and subsequent control of production machines. An important aspect of data processing that is becoming increasingly necessary is the classification of information and its retrieval. For technical and other libraries a centralised real time computer system could be comprehensive and up to date. For many scientists and engineers the computer took over from the slide rule some time ago. For designers it is now taking over from the drawing board as well in the form of an electronic sketch pad using a light pen on a cathode ray tube display. Computer aided design includes: retrieval of design information; calculations; production of detail drawings and numerical control of machine tools. Designs already using computers include: gearboxes; pipe runs; textiles; architecture; electrical circuits and appropriately various aspects of computer design.

It would seem that we have missed our place in the early stages of computer development. It is no longer a question of looking forward to a computer. We must be ready to make use of large fast central processors and new desk top computers. There are two ways in which we can start preparing for tomorrow now:

Firstly. We must have maximum computer education in the Corps now. We can educate ourselves through the Royal Signals and Royal Military College of Science courses or better still with a desk top computer, or an "old" computer, for training at Chatham. Further experience must be gained by hiring computer time for projects. A good general education is required. The main failure is failing to appreciate the advantages to be gained and the uses to which a computer can be applied.

Secondly. We must produce a few frequently used programmes in order to justify field machines which will probably only be desk top computers. The sort of programmes required are: calculation of earth moving quantities; optimum deployment of resources to demolition tasks, ordering of bridging stores and river crossing planning.

This should mean that in a few years time we have our own field computers and are ready to plug into the military and national computer grids when the time comes. Computed!

Portsmouth Cathedral D Day Fellowships

NEXT YEAR is the twenty-fifth anniversary of D Day, and in Portsmouth, from which the bulk of the Allied forces set sail for France in 1944, and where an ambitious project is afoot to complete the Cathedral as a D Day memorial, an organization has been formed to keep alive the memory of D Day and all it stands for.

Membership of the D Day Fellowship is not confined to those who took part in the D Day operations. Parents and other relatives may also belong. The life subscription is £1 and those joining will receive a certificate of membership. Linked with the Fellowship will be an annual service in Portsmouth Cathedral on or about the anniversary of D Day and a special book containing the names of the members which will be placed within the Cathedral.

The funds raised will help to complete the nave of the Cathedral, a project which has been designed by the British architects, Seely and Paget, in collaboration with Professor Pier Luigi Nervi, the famous Italian structural engineer, who built the Olympic stadia in Rome. Seating 1,500, the nave will have a roof span of 78 feet, nearly double that of St Paul's Cathedral. The plans have been approved by the Royal Fine Art Commission.

Empanelled in the ceiling of the ambulatory surrounding the nave will be the crests of the units of the Allied nations which took part in the D Day operations. There will be space for 400 badges, and designs and layout plans are in the hands of a Services committee representing Britain, the USA, Canada, Australia and New Zealand and other Allied nations.

A stone commemorating the resolve to complete the nave as a D Day memorial was laid in the Cathedral two years ago by Field Marshal Lord Montgomery. In a message published when the Portsmouth Cathedral Completion Appeal was launched, Lord Montgomery said: "What we began on June 6 1944, has made possible a new life for nations all over the world and new hope to millions, who, but for our efforts, would be living in slavery and darkness. . . . It is indeed fitting that this day, which marked a turning point in the history of mankind, should be marked by the completion of a cathedral in which there can be enshrined a lasting reminder of the things for which we then fought."

Those wishing to join the D Day Fellowship should write to the Organizer, the Portsmouth Cathedral Completion Appeal, Flat 2, Cathedral House, St Thomas's Street, Old Portsmouth. (Line drawings and photographs of artist's impressions of the completion project are available on application to the Appeal Office, Flat 2, St Thomas's Street, Old Portsmouth. Telephone: Portsmouth 23164).

Covenants

ARE you a covenant subscriber to the Institution of Royal Engineers?

Anyone who pays the standard rate of UK income tax on any part of his total income and enters into a seven-year Deed of Covenant with the Institution increases the value of his annual subscription by 70 per cent—at no cost to himself.

For instance, if your annual subscription is say £3 then you have to earn £5 2s 2d to pay the Institution that sum at the present standard rate of income tax of 8s 3d in the £. In the case of a covenanted subscription the Institution can claim each year the tax element of £2 2s 2d; whereas if your subscription is not covenanted, you still have to earn £5 2s 2d to pay it but the Inland Revenue retains the tax element to the Institution's dead loss. Over the seven-year period of a covenant the Institution will receive £35 15s 2d, as against £21 in the case of an uncovenanted subscription. The figures are proportionally the same for other annual subscription rates.

The Council is most grateful to all those Members, amounting to just over half the total membership, who do covenant their annual subscriptions and thereby bring great financial benefit to the Institution of Royal Engineers.

The Council feels, however, that there must be many other Members who are either unaware of the Institution's Covenant Scheme, or who confuse it with other Covenant Schemes, operated by the amalgamated Royal Engineers Association/Royal Engineers Benevolent Fund and the Royal Engineers Officers' Charitable Fund, and may not be sure whether they are covenant subscribers to the Institution or not. To clarify this latter point a *C* has been placed against the names of Members in the Royal Engineers List who subscribe by Deed of Covenant, and an *I* against the names of those who are Members of the Institution but are not covenant subscribers.

If there is an *I* against your name in the RE List, why not write for full particulars of the Covenant Scheme to The Secretary, Institution of Royal Engineers, Chatham, Kent?

Correspondence

Major G. J. L. Coltart,
Heriot-Watt University,
Darien Building,
Bristo Place,
Edinburgh 1
13August 1968

THE WORKING RELATIONSHIP BETWEEN FIELD SQUADRONS AND SPECIALIST TEAMS

Sir,—This paper by Major Cave ventilates a real problem, but I feel proposes the wrong remedy. The description of the three exercises in the paper illustrates the wide range of engineering expertize in the present "Field Squadrons", and the differences in their approach to a major technical task. The need in my opinion is not to change the relationship between the specialist team and the squadron, but to ensure that the squadrons employed on such tasks are suitably trained, equipped, and oriented for them.

The Far East Field Squadron (Airfields) was an all tradesmen unit, whose members, at all levels, had been continuously employed in the planning and execution of high class permanent engineering works for at least eighteen months prior to the exercise. The Squadron had thus both the skills and the organization necessary for tackling any type of work, and had also a tradition of producing work up to normal contractual standards and rejecting any work below these.

The UK field squadrons on the other hand are basically combat engineering oriented, with few tradesmen, and very limited opportunity to practice them in their trade. The result is that these squadrons have a different philosophy and lack the supervision and technical skills necessary for high class engineering works.

The results of the three POL exercises could, therefore, have been predicted.

The consultant/contractor relationship will produce satisfactory and timely completion of any engineering work if both the consultant and contractor are competent at their jobs. The military requirement is for a sufficient number of suitably trained squadrons to carry out works with a high technical content. This would imply that every theatre should have at least one field squadron (construction) similar in composition and equipment to the three field squadrons (airfields) and that these squadrons should be continuously employed in civil, mechanical and electrical engineering works.

In addition to providing the necessary "contractors" this would free the remaining field squadrons for close support combat engineering training, and raise their efficiency in this field.

If this course were followed I believe that the specialist teams could expect to work with units which are experienced "contractors" and that the problems described by Major Cave would be resolved.—Yours faithfully, G. J. L. Coltart.

USE OF PRILLED AMMONIUM NITRATE/FUEL OIL AS AN EXPLOSIVE

"It could have been inferred from the article on the Use of Prilled Ammoniam Nitrate as an Explosive which appeared in the September 1968 issue of the *RE Journal*, that MOD (Army) had given temporary permission for this explosive to be used. In fact no such permission has been given, although FARELF was authorized to use AFNO, but only on the POST CROWN project.

The situation at present is that MOD (Army) are looking into the problems connected with giving approval for the use of ANFO, and if these problems can be overcome approval will be given subsequently for its use in accordance with instructions regarding the ingredients, the mixing and the handling. Until this approval is given the use of ANFO within the British Army is against the regulations. It is unlikely that approval for its general use by RE units will be given this year."

EDITOR

Memoirs

MAJOR-GENERAL S. W. KIRBY, CB, CMG, CIE, OBE, MC*

MAJOR-GENERAL STANLEY WOODBURN (PETER) KIRBY, who had been Director of Staff Duties and Deputy Chief of the General Staff in India, Director of Civil Affairs at the War Office, Deputy Chief of Staff of the British Element of the Control Commission for Germany and principal author of the official history of the *War Against Japan* died on 19 July 1968 at the age of 73.

Elder son of Sir Woodburn and Lady Kirby, he was educated at Charterhouse and the Royal Military Academy, Woolwich and was commissioned into the Royal Engineers one month before the outbreak of the First World War, aged 19.

He served with the 22nd and 28th Signal Companies RE in Salonika and Egypt; he was mentioned in despatches and awarded the Military Cross and Bar for gallantry and devotion to duty in the field.

He returned to Chatham for a Supplementary Course in 1919 after which he became an Assistant Instructor in Survey. From October 1923 until the end of 1926 he was employed on survey duties in Malaya and was awarded the OBE for his work there. After a year in the Military Intelligence Branch of the War Office he passed into the Staff College, Camberley. As was customary in those days, he did a year's regimental duty before taking up a staff appointment on graduating from Camberley. The year was spent in command of 23 Field Company RE, then part of the 1st Division at Aldershot, after which he served for four years in the Military Operations Branch of the War Office, being made a brevet lieut-colonel in 1934.

Early in 1935 he was posted to Malaya where he held two short appointments in command of the 41st (Fortress) Company RE and as ACRE Changi District before returning home the following year to attend the Imperial Defence College as a brevet colonel.

On leaving the IDC he was posted in 1937 to the Master-General of the Ordinance Department at Army Headquarters India becoming a brigadier and Deputy Master General of the Ordnance when the Department expanded on the outbreak of the Second World War in September 1939. He was promoted Major-General in 1941 on becoming Director of Staff Duties and in 1942 he became Deputy Chief of the General Staff. During his arduous years at Army Headquarters he was concerned with the early stages of the gigantic build up of the India base and the organization and expansion of the military forces, based on India, that held off invasion and later triumphed over the Japanese. For his outstanding services he was created CIE in 1940 and CB in 1943.

In June 1943 he was recalled to the War Office to become the first Director of the newly established Directorate of Civil Affairs (Military Government), and in July the following year he was released from that appointment to set up the British Element of the Control Commission for Germany. With Sir Ivone Kirkpatrick, who dealt with the civil side of the Commission, General Kirby became the military Deputy Commissioner and he held that appointment until his retirement in February 1947. For his services he was created CMG and was honoured by the Governments of the USA, Belgium and the Netherlands.

General Kirby was a prolific writer, during his Army service his most outstanding work was a series of booklets, published in 1931 and 1932, on Tactical and Administrative Schemes. In 1950 he was appointed principal author of the official history of *The War Against Japan*, and nobody could have been better chosen for the post. He and his colleagues had no easy task since British documents connected with the disastrous surrender of Singapore and the retreat through Burma were lacking, and the long struggle back through the Arakan to ultimate victory, being largely a

Major-General S Woodburn Kirby,
CB CMG CIE OBE MC

war of attrition, did not lend itself to dramatic narrative. However, aided by the availability of Japanese records, he and his team were able to produce, between 1958 and 1968, the five volumes of the official history of the *War Against Japan*. The printers' proofs of the final volume were received shortly before his death. He brought to the task tremendous enthusiasm and energy and succeeded in getting the terms of reference for the series to cover the campaigns in the Pacific. The result has been the only comprehensive history of the war in the Far East.

As a Captain, Peter Kirby married Rosabel, elder daughter of Mr and Mrs Gill, at St Andrew's Cathedral, Singapore. They had one son. She died in 1954 and in October 1955 he married for the second time Mrs Joan Catherine, widow of Stuart Catherine who survives him.

In his retirement General Kirby will be gratefully remembered for his long association with the Royal United Kingdom Benevolent Association of which he was a committee member for many years thus preserving a family connexion with the Association that through his father and grandfather had lasted over a hundred years.

Book Reviews

GEORGE LAWSON
SURGEON IN THE CRIMEA

Edited by VICTOR BONHAM-CARTER assisted by MONICA LAWSON
(Published by Constable, London. Price 35*s*)

George Lawson was a student in the Medical Department of King's College Hospital from 1848 until 1851. He joined the Army as an Assistant Surgeon in early 1854 and, after purchasing his uniform which put him into debt to the extent of a year's pay, he proceeded to Malta and then on to the Crimea. This book relates his experiences as recorded in letters written by him to his family in 1854 and 1855 which have been edited, enlarged and explained by Victor Bonham-Carter and Monica Lawson, his granddaughter.

One requires no medical knowledge to understand this very readable record of the sufferings and privations of all, officers and men, who took part in the Crimean campaign; of the muddle and indecision, of wounded men lying for days in the open in the depth of winter because the means of transporting them to hospital just had not been provided, of cholera, typhus and pneumonia which killed off three times as many men as did the enemy, of the grossly over-crowded and ill-equipped hospital ships of the divided responsibilities of the Commissariat, the Medical Department, the Ordnance Department, the Quarter-Master-General and the Adjutant-General, an antedeluvian system which produced a multitude of overlapping authorities but little action or decision.

George Lawson was an interested observer of all that went on around him and sent to his family details of the country, the people and the conditions under which they lived. He passed on the gossip of the soldiers and the tittle-tattle of the officers in his immediate circle and he remained cheerful and optimistic despite his privations.

This book serves as a reminder of the backwardness of medical science one hundred years ago and underlines the enormous steps forward made by the Army Medical Service between then and now. It is of interest to read that the great Florence Nightingale never believed in the existence of germs even though she lived until as recently as 1910.

But out of evil came good and the findings of the various Boards which assembled to investigate the muddle and mismanagement of the Crimea did much to ensure that never again would the British go to war hamstrung by a multiplicity of Staffs and Departments, each working in its own watertight compartment.

A most interesting book which gives a detailed and frank account of conditions in the Crimea campaign as seen through the eyes of a very junior surgeon.

H.J.

PHYSICAL METALLURGY OF ENGINEERING MATERIALS

E. R. Petty, BSc, PhD, AIM

Senior Lecturer in Physical Metallurgy at Sheffield College of Technology

(Published by George Allen & Unwin Ltd, London, 1968. Price 45*s*)

The 300 pages of text, tables, photographs and appendices of this book were compiled to meet the needs of University and of Technical College students at, and beyond, Higher National Certificate level. It is the sixth of the modern metallurgical texts published under the sponsorship of the *Institution of Metallurgists* and edited by Professors C. R. Tottle and J. C. Wright of the University of Bath and the College of Advanced Technology, Birmingham, respectively.

The text is divided into two main parts.

Part 1 deals with the basic properties of the more important metals and some of their alloys, and consists of six chapters which individually cover: the light metals, copper and its alloys, the white metals, the alloying metals, iron and steel, and the refractory metals.

Part 2, of seven chapters, deals with the selection of materials for their specific properties and covers: ease of fabrication, availability and low cost, high strength, low and high temperature, springs, wear resistance, anti-corrosion and oxidation, and those with other special physical properties.

The fourteen appendices list the properties and applications of some alloys, several types of steel and iron, and some of the magnetic materials and permanent-magnet alloys.

The text is concerned mainly with those materials of commercial importance as used in everyday production work—although the characteristics of some newer and semi-conducting materials are discussed.

F.T.S.

MANUAL OF MAINTENANCE ENGINEERING

Edited by Richard Clements, BSc(Hons), FLS

(Editorial Director, Factory Publications Ltd)

and

Dennis Parkes, MIPlantE, MAmerIPE

(Editor *Maintenance Engineering*)

(Published by Business Publications Ltd, 180 Fleet Street, EC4. Price 11 gns)

This book is the combined volume of Manual of Maintenance Volume 1: Buildings and building services, and Volume 2: Plant. The individual volumes were published in 1965 and 1966 respectively.

The text consists of thirty-three monographs written by individual authors specializing in their subject matter, normally employed in a variety of research establishments, national councils and commercial concerns.

The papers dealing with buildings and building services cover: maintenance management, corrosion prevention, factory cleaning equipment, heating installations, planned maintenance of lighting equipment, roofs, fire protection, walls, trade waste treatment plants, electrical installations and equipment, floors, structural preparation and painting, ventilation and air-conditioning, piped services and rainwater gutters and drains.

The plant papers cover: The maintenance department, mobile equipment, repair and reclamation, hydraulic systems, lifting tackle, office equipment for maintenance control systems, safety practices and equipment, boilers, dust control. The Factories Act and other Regulations affecting maintenance, valves, lubrications, cranes, conveyors and lifts, fuel oil installations, pneumatic systems, the maintenance workshops, pumps scaffolding and staging.

Each paper contains its text within thirty odd pages, inclusive of photographs, diagrams and tables, but it is fair to say that these summaries are excellently compiled and contain the major factors which engineers need to observe, and carry out, if they wish to maintain accommodation and installed equipment to a high serviced condition.

For engineers in charge of plants in remote areas, away from technical libraries and subject to spares provision delay, this 1,000-paged compendium would prove a practical blessing.

F.T.S.

ELEMENTS OF STATISTICS

C. G. Lambe, PhD

(Royal Military College of Science)

(Published by Longmans, Green & Co, 48 Grosvenor Street, London, W1. Price 25*s*)

This is the *Second Revised Edition* of the book first published in 1952, and it is of statistical interest to note that whereas the first edition was produced with a stiff bound cover and priced 8*s* per copy, the second edition, with flexible paper cover and some thirty odd extra pages of text, is priced at 25*s* per copy—undoubtedly due to the increased costs of labour and materials.

This work has been written primarily for the use of engineering students and laboratory workers of reasonable mathematical ability whose fields of endeavour in research, production and development require a knowledge of the scientific treatment of numerical data. It is, therefore, of particular interest to technical staff officers of the Armed Services.

The text, with the aid of definitions, worked examples and tables, will enable the reader to learn the language of statistics, and advise how best to collect information and treat it in order to analyze data and study its relation to other data presented to him.

The extra text provided, in this the 1968 edition, covers Sampling Inspection and Significance Tests.

F.T.S.

ENGINEERING MATERIALS FOR MET PART I

L. C. Mott, Farnborough Technical College

(Published by Oxford University Press, Ely House, London, W1. Price 15*s*)

The purpose of this book is to present to *Mechanical Engineering Technicians* who are in their first two years of the City and Guilds of London Course 293, and students of the General Engineering Course 287, the methods of manufacture, properties, testing and subsequent processing of the most common engineering materials in present-day use.

The 110 pages of text, tables and exercises cover iron and steel, copper and its alloys, anti-friction materials, light metals and their alloys, miscellaneous metals and alloys, plastics and rubber, non-metallic materials. In consequence the references to individual materials are, of necessity, very brief, but the summary tables at each section end include a wealth of data concerning composition and properties.

Included also is a table of the mineral deposits found in the various countries of the world, and one hundred exercise questions for students—the latter being annotated with the relevant text sections to which the questions are applicable.

This is an excellent primer for the students for whom it is intended—and its style is suitable for the interested layman.

F.T.S.

GENERAL ENGINEERING SCIENCE G1, G2 and G*

R. J. Besanko, AIMarE, AMIPlant E

Lecturer, Dept of Engr Brooklyn Technical College, Birmingham

and

T. H. Jenkins, BSc, AMBIM, AFIMA

Vice-Principal, Foley College of Further Education, Stourbridge

(Published by Oxford University Press, Ely House, London, W1. Price 16*s*)

This book has been compiled to meet the needs of craft apprentices and intending technicians undergoing the two years part-time study courses (G1, G2), and the special one year course (G*), in General Engineering at Technical Colleges with the aim of sitting the appropriate examinations of the City and Guilds of London or Regional Examining Bodies or Unions.

The text is, therefore, presented as precisely as possible in a series of logical sequences which define the particular subject item, give one or more worked examples of problems and then sets questions for the students to solve. An excellent method of "ramming-in" the gist of Course lectures to students in their out-of-school hours. In effect the content presentation is similar to that adopted by some correspondence teaching systems.

The text is given in twenty-three sections and covers: measurement and units, forces, force and turning effect, centre of gravity, force and materials, friction, work, energy and power, velocity and acceleration, force, motion and torque, heat and temperature, quantity of heat, heat and change of state, heat and expansion, mechanical equivalent of heat, heat and gases, electric current, electric circuits, resistance and temperature, laws of electrolysis, primary and secondary cells, electrical energy and power, magnetism and electromagnetism, alternating current and voltage.

This soft-covered book is an excellent primer and well worth the modest price of 16*s*.

F.T.S.

THE LINE OF BALANCE METHOD

PHILIP LUMSDEN

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 18*s*)

The Line of Balance Method is a management technique which was developed by the US Navy Department in 1942 for the programming and control of repetitive or one-off projects. It was not used much in this country for some years as it was overshadowed by the Critical Path Method of planning. However, the almost universal acceptance of network techniques as an established logical discipline for planning and progressing complex projects has resulted in a recent awakening of interest in the Line of Balance Method and in particular its application on repetitive work such as large housing projects.

In this book, the author describes the method in simple terms and has illustrated his text with very clear diagrams which make this relatively complex subject interesting and easy to understand. In Chapter 2 he describes the conventional rules and definitions which are generally accepted for network analysis and from them develops the Line of Balance Method. In succeeding chapters, the method is logically developed to show its application in both the planning and execution phase of a large project. Throughout the book the use of the method is directed towards a building project and the examples are related to this industry although it is also made abundantly clear that the method can be equally well applied to most other industries requiring management control of repetitive operations.

This is a well written and well illustrated book on a very useful planning technique. It is particularly useful for repetitive operations but is of less general application than the Critical Path Method with which most RE Officers are now familiar.

R.C.G.

COMPUTER PROGRAMMER TRAINING IN ICT

P. LAMBERT

(Published by Pergamon Press Ltd, Training and Technical Publications Division)

This is a monthly publication produced as part of a reference series describing programmed instruction in industry, and each booklet is an actual case history. The authors are all practical training men drawn from the companies concerned. This particular booklet describes how the author developed and used programmed learning to teach a computer programming language.

Initially, the author used a branching multiply choice programme of approximately 1,500 pages or "frames". This programme was applied to two separate student groups, one using film version on a ITM Grundytutor teaching machine, and the other groups used scrambled texts.

The results gained were interesting. The machine taught group achieved higher average marks in the post-test, and were quicker through the programme. However, neither result was statistically sound because of the small number of students. But when those students were tested against classroom taught students, the programmed students achieved marks nearly 20 per cent higher, and yet their learning time was halved.

Perhaps the most important fact was the realization that the programmed learning approach did not practice the written skill. For instance, the student may learn that the code STO means "place the data into store", but he would be totally unaware of how to actually apply it. The only practical skill exercised by the student was pressing a button or turning pages. The student must therefore be given some form of constructed response. Classroom teaching gave this response.

The author therefore made the second attempt by improving the features of the first, and in particular the contents of the page or frame were made larger to put information to be learned into a descriptive background which he called the "extended linear technique".

The author applied this new technique to two groups of students learning a brand new computer language. One group were experienced programmers in other languages but had never before seen the new one. The second group has just completed the basic course, and had not therefore practiced their newly acquired knowledge. Test results showed that the experienced student absorbed the new language twice as fast and achieved a 10 per cent higher result than his less experienced neighbour.

This last sentence has great significance, particular in a military technical training environment, where candidates are drawn from a wide variety of backgrounds.

This booklet offers many interesting features, which can be applied to large numbers of teaching situations.

D.R.T.

TITLE PROGRAMMED INSTRUCTION IN INDUSTRY VOLUME I

(Published by Pergamon Press Ltd, Industrial Training Division. Price 60*s*)

This is a reference series of monthly booklets describing Programmed Instruction work done in Industry. The series reflects the user's viewpoint and the authors of the eight Case Histories are practical training men drawn from the companies involved.

Programmed Instruction in BEA

This is an account of BEA's experience in PI over the last five years and relates how the approach to PI was organized and how it was received by the operating departments. The extent of the use of PI over the five years is carefully analyzed and the proposals of the future approach in light of the experience gained, are fully discussed.

A World Wide Experiment in Staff Training

This is a study of the development of PI within the Royal Dutch/Shell Group and describes the efforts made to train overseas representatives in the essential basic knowledge which every salesman in the reseller market world-wide ought to possess.

It is a fascinating account of the disappointments, the difficulties and errors which occurred in the early stages and the ultimate success which was achieved.

The reasons for embarking on an experiment using PI are detailed along with the problems encountered and the solutions found.

The author of this Case History was at one time an instructor at Sandhurst and was also engaged in training instructors in the Army.

A Training Course for GPO Telephonists

The GPO have become increasingly involved in PI over the last five years. The use of PI demands a systematic analysis of training needs and the GPO have discovered from this analysis ways of improving both the content and method of existing training arrangements.

The author gives a detailed account of how programmed techniques have been introduced for the training of telephonists and the economies which have resulted.

Basic Workshop Training in ICT

The author pioneered PI techniques at the Apprentice School of International Computers and Tabulators and has written a number of programmes which are in current use.

This monograph contains a description of how PI has been used as part of an integrated training system in which the learning of workshop theory by programmes was applied in conjunction with graded practical exercises in Fitting, Turning and Milling.

The author gives tables of the results achieved, drawing general conclusions: he outlines the saving in time and improvement in efficiency, and gives his view on the implications of such an integrated scheme for other engineering companies.

An Analytical Approach to BEA's Secreterial Training

BEA carried out an exhaustive investigation into tasks which their secretaries had to perform and their relative frequency and importance. From this research a programme was prepared and put into use.

The author gives an account of the preparatory work which was required and the procedure adopted to test its effectiveness thoroughly.

The success and failure of the programmed provides a warning from expecting too much from a purely verbal programme but raises some interesting questions which merit further study.

The Use and Cost of PI at Stewart and Lloyds

The author of this section is the Group Education Officer of Stewart & Lloyds and has spent many years operating and researching in education and training.

A history of the development of PI at the Corby Works in Northamptonshire is given It describes the initial approach to the use of PI techniques showing how they have influenced the development of industrial education and training, and gives a detailed account of the costs involved.

Improved Technical Training by HATRA

The Hosiery and Allied Trades Research Association (HATRA) was established as a research organization for the hosiery and knitwear industries.

The problem of establishing Quality Control over the large number of small firms in the industry has resulted in the use of PI in training courses run by the Association.

This booklet deals with the experience obtained in just one aspect of technical training and indicates the many advantages as well as limitations of this training method.

Case Studies in the use of Algorithms

The eighth and last Case History in this series does not deal with PI but describes the algorithmic method of approach to training problems. These techniques make extensive use of "algorithmic" flow charts which specify, for every major contingency, what a reader should do. The aim of this monograph is to outline these techniques, to delineate their potentialities and limitations and show how they have been applied. Several sets of evaluation data are presented and some typical forms of hostility are considered.

I.J.P.R.

Technical Notes

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*, June 1968

CONSTRUCTION RAWCLIFFE BRIDGE by J. A. Dunster, BSc(Eng), ACGI, MICE, and N. E. Hough, MIStructE. This bridge which spans the Dutch River in the West Riding of Yorkshire is of special interest because it is the first epoxy-jointed concrete bridge in Britain. The testing and selection of the epoxy resin adhesive to be used for jointing the beam segments was described in the special bridges feature in the April edition. This month's article describes the method of construction and includes some very clear and interesting diagrams.

TRANS BAY TUBE CONSTRUCTION IN THE USA. This article is a short but extremely interesting account of the laying of a large tube 3.6 miles in length across the floor of San Francisco Bay. The tube will carry two railway tracks and thus provide the vital link in the $1,200 million San Francisco Bay Area Rapid Transit system.

The tube is being laid in sections, averaging 330 ft in length. Each section is binocular shaped, 21 ft 6 in high and 48 ft wide, and contains two inner tubes, each 17 ft in diameter one for each rail track.

The article describes how, after fabrication, each section is floated to a nearby outfitting wharf where about 4,200 cu yd of concrete is added to form the 2 ft 3 in thick interior walls and the trackway. Each section is then floated out into position and sunk on to a prepared bed which at places is 130 ft below the surface. For this operation the contractor designed and built some massive and ingenious floating machinery which is well described in this very interesting article.

CLYDE SUBMARINE BASE FOR POLARIS FORCE. This article, which is of a general nature, describes the work involved in the construction of the first naval base to be built in Britain for more than fifty years. The base which is at Faslane on the Gareloch is to house Britain's Polaris submarine force.

The base is one of the largest construction jobs undertaken in the UK in recent years and represents just over five years of intensive effort by the Ministry of Public Building and Works, who planned and organized the construction work for the Ministry of Defence, and by specialist teams of contractors. As well as describing the civil engineering aspect of this project a brief account of the highly sophisticated system for the supply of mechanical and electrical services is also given.

Included in this month's edition is the second part of Kerisel's and Quatre's article on the estimation of settlement under foundations based upon the results of the triaxial compression test. This part deals with the computation of stresses at depth and subsequent settlement below a non-rigid foundation.

J.L.B.

Notes from *Civil Engineering and Public Works Review*, July 1968

THE INSTITUTION OF CIVIL ENGINEERS—A HISTORICAL SURVEY. This article was being prepared by the late Alexander McDonald, CBE, BSc, MICE, when he entered hospital for his last, fatal illness. It was therefore completed and edited by V. J. Wilmoth who had previously discussed it with Mr McDonald. It will be of great interest to RE Officers as Military Engineers were closely connected with the founders of this revered Institution. The term "civil engineer" was first used by John Smeaton at the end of the eighteenth century to embrace all forms of engineering outside the military field and it was in this content that the title of "The Institution of Civil Engineers" was adopted by the Founders. To be strictly correct, therefore, there are only two engineering professions—Military and Civil. This article describes the first meeting of a group of young engineers in 1818 to debate a paper by Henry Robinson Palmer on the formation of a society for promoting regular discourse between persons engaged in the profession and how subsequently Thomas Telford, an already famous engineer, was invited to become the first President. It describes the formation of the Institution and briefly traces its history to the present day.

The remainder of this edition is devoted to a series of short articles on various civil engineering projects which are at present in course of construction. Three of particular interest are:

Western Avenue Extension—Crossing the Grand Union Canal. This article is one of a series prepared by G. Maunsell and Partners, Consulting Engineers on this £15 million project for the Greater London Council. It describes the construction of a 3,200 ft length of elevated structure between an abutment west of Lord Hill's Bridge and an abutment at Paddington Green.

Cambridge Fender for Large Ships. A brief description is given by Sir John Baker, OBE, ScD, FRS, MICE, of a new type of fender, capable of absorbing the very large amounts of kinetic energy required in berthing very large ships and, in particular, super tankers. The design is based on the principle of energy absorption by the plastic deformation of metal. Mr P. W. Turner, who designed this particular fender, uses a torque tube and plastically deformable torsion bar as the energy absorbing media. Plastic deformation of metal has been used in the past for protective fendering of bridge abutments but the use of this principle for resilient fenders is a new departure.

Construction Techniques for Expansion and Construction Joints in Water Retaining Concrete Structures. This very good article, by W. T. Brooks, gives a brief description of modern methods and techniques for providing expansion and construction joints in water retaining concrete structures. It is well illustrated and would provide an excellent guide on this subject to the RE Officer who is called upon to build a water reservoir or more likely a swimming pool.

R.C.G.

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Stability of Earth Embankments by E. Spencer, MScTech Lecturer in Department of Civil Engineering, University of Manchester, Institute of Science and Technology.

This article explains how the factor of safety for the stability of an embankment depends to a considerable extent on the method of analysis. In general, the more rigorous type of analysis leads to a higher value for the factor of safety than that given by a more simple method. The article presents the main factors which influence this discrepancy, and, in addition, provides a set of charts which may be used with the simple method of analysis to identify the position of the critical slip circle and to choose a slope for an embankment corresponding to a specified value for the factor of safety. The article is supported by a worked example illustrating the use of these charts.

The Design of Vertical Cantilevered Walls. The author, D. R. C. Branch, BSc, of Woodall-Duckham Limited, shows that, with his design charts, the complete design of any vertical cantilevered wall under any combination of triangular and uniformly distributed loads, can be made very simple. The first half of the paper sets out the theory behind the formulation of the charts and the second half illustrates their use with two examples.

This months magazine also includes a short but interesting article which outlines the main conclusions reached at the first conference on the significance of defects in welds which was held last year.

J.L.B.