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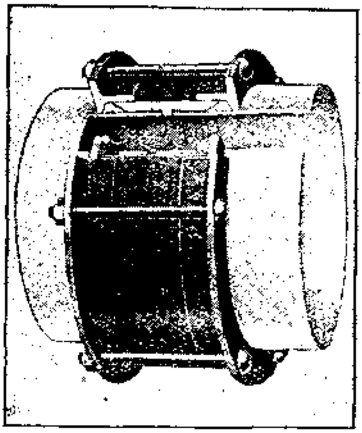

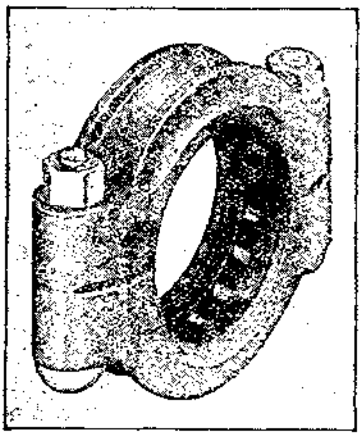

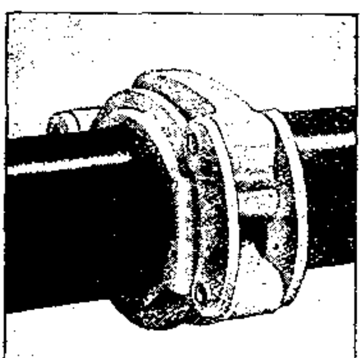

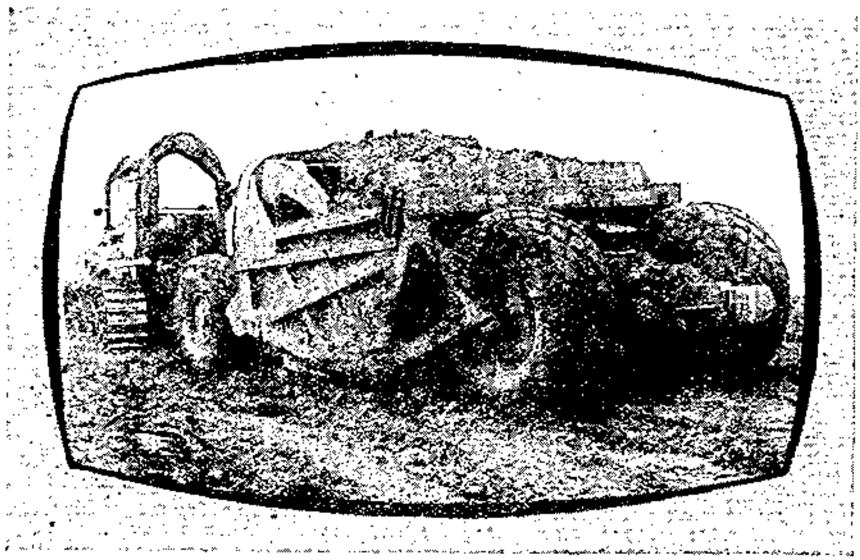

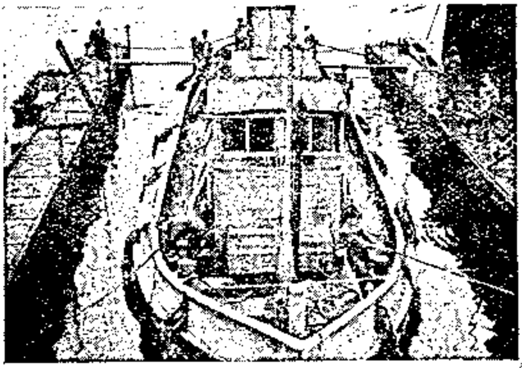

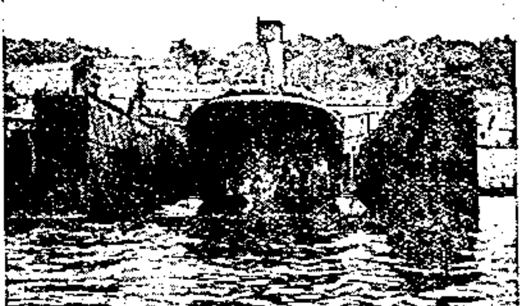

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Photo 1.—Clifton Suspension Bridge.

Photo 2.—Atmospheric system on South Devon Railway.

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BRUNEL—A GREAT ALL-ROUND ENGINEER

By LIEUT.-COLONEL G. C. L. ALEXANDER, O.B.E., T.D., R.E.

THIS is a short account of the professional life of a man who died at the early age of 53, who, during his brief span of life, was responsible for the design and execution of many triumphs of engineering skill, knowledge and perseverance, several of which stand to this day as memorials to him. I feel that Royal Engineer officers can learn much from his career of amazing versatility, and I commend his life as a very worth-while study.

Isambard Kingdom Brunel was born on the 9th April, 1806, at Portsmouth. The son of a distinguished father, Sir Marc Isambard Brunel, a naturalized Frenchman, and an English mother, Brunel the younger thought in terms of engineering almost from his cradle.

Brunel was indebted to his father not only for the inheritance of many natural gifts, and for a professional education, but also for those qualities of forethought and perseverance which alone can ensure attainment of great designs.

He commenced school life at the age of 8 years under the Rev. Weeden Butler, but even before that had been taught Euclid by his father; from an early age he had evinced a marked talent for drawing.

Brunel was engaged in his father's office from the year 1823, and before he had reached 21 years of age had become one of his father's chief assistants on the work of driving the tunnel under the River Thames, the flooding of which nearly cost him his life. The accident referred to was the first flooding of the tunnel, which occurred in May, 1827. Brunel's promptitude on the 27th June was an example to his men in proceeding along the flooded tunnel (which could only be accomplished by boat) to the head of the tunnel to examine the frames. Even the best of his men were at first much alarmed at the danger they were in, and Brunel's action quietened their apprehension.

I now quote an extract from a letter from a Mr. R. H. Marten to Brunel, Tunnel Works, Rotherhithe, dated 9th November, 1827:—

"Accept my congratulations on your having completed 20 feet of the tunnel since the accident, and my thanks for your kind remembrance of me at your little festival of exultation for tomorrow evening. My son George will, with your permission, be my proxy, and his age and lively disposition (for my spirits at present are far from joyous) will suit your party better than my age will permit. Let me, however, give you a caution. You are about to dine in the tunnel and I am not without fear of your all suffering from the damp atmosphere if you sit long there. Take care, too, of over exhilaration. Babylon was captured because of carelessness during a feast, and your enemy, the Thames, has at first a silent, wily manner of approach, till he has gained his point, and then he is an irresistible thunderer. Beware, therefore, of slips and mind to break up early, so as not to endanger either your health or your sobriety. The eyes of the world and eyes of more importance still will be open upon your proceedings: therefore be careful, and especially as it is the eve before the day of rest which is commanded to be specially remembered."

A brief account will be given of some of the major works for which Brunel was responsible.

Clifton Suspension Bridge

In the autumn of 1829, Brunel, then 23 years old, heard that designs were required for a suspension bridge over the River Avon at Bristol, and he decided to compete.

Brunel was appointed Engineer of the Clifton Suspension Bridge in 1831, his designs being preferred to those submitted by Mr. Telford, the designer of the suspension bridge over the Menai Straits.

The Marquis of Northampton laid the first stone of the abutment on the Leigh Woods, or Somerset, side of the river in August, 1836. The abutment was not finished until 1840, great delay having been caused by the contractor, which misfortune led to a large excess expenditure. As all efforts to raise more money by way of subscriptions were unsuccessful, the scheme was abandoned in 1853. Several proposals for completing this bridge were made in Brunel's lifetime, but it was not until about one year after his death that the superstructure of the bridge was commenced.

In 1860, work was resumed by a company formed of some of the members of the Institution of Civil Engineers, who had an interest in the bridge as forming a monument to Brunel. The bridge was opened in December, 1864.

The chains were brought from the Hungerford Suspension Bridge, at that time in course of demolition. Some modification was, however, necessary in Brunel's drawings, in order to adapt the Hungerford Bridge chains, and there are three chains instead of two, as in Brunel's design. The clear width of the bridge is 30 ft., 5 ft.less than originally intended. No attempt has been made to complete the towers according to Brunel's drawings. (See Photo 1).

The Clifton Suspension Bridge competition enabled Brunel to make his name in the engineering profession, and all his subsequent successes were traced by him to this achievement. His connexion with the scheme in its early stages forms an important passage in the history of his life.

The Bristol to London Railway

In 1832, a committee was formed of representatives of the Bristol Corporation and other public bodies of Bristol, to carry out the plan of the construction of a railway to London.

Perhaps no better example of Brunel's character can be given than by quoting an account of the attitude he took up towards some of the members of this committee immediately before his election. Some of the members decided to select their engineer by means of a competition among the candidates as to which of them would provide the lowest estimate. Brunel at once asked that his name be withdrawn, intimating that such a criterion merely put a premium on flattering promises and would appeal most to the man who had least reputation to lose and cared least about losing what he had already. The idea was dropped. Brunel obtained a majority of the votes, and was appointed to the position of Engineer to the Great Western Railway on 7th March, 1833.

He immediately set to work on the preliminary drawings of the proposed railway to London. Within a month he had reconnoitred and mapped out the entire route.

The title "Great Western Railway" was first used officially at the meeting of the board, consisting of a body of Bristol directors and a similar representation of London directors—forty persons in all—held in London on 19th August, 1833. In that year, the first prospectus of the Great Western Railway was issued.

Brunel had the choice of going either south or north of the Marlborough downs in laying out the route of the railway between Reading and Bath. He selected the northerly way for two reasons. Firstly, this way gave easier gradients and gentler curves, both of which were very important for the high speed of travel which Brunel had in mind. Secondly, it would afford easy extensions to Oxford, Gloucester, and other large towns; also a more convenient way into South Wales.

George Stephenson was also of the opinion that the route selected was the best possible, but although from many aspects Brunel was right in his location of the line, the deviation northward through

Swindon did give rise to an old description of the Great Western Railway as the "Great Way Round", and the direct service to the west is now run via the old Berks and Hants line, which has been adapted for express running, and linked up at Cogload Junction with the old main line via the Stert and Westbury and Castle Cary–Longport cut-offs.

On the route from London to Reading many obstacles had to be surmounted. Undoubtedly, the chief obstructions were the Brent Valley at Hanwell, the River Thames at Maidenhead, and the hill between Twyford and Sonning.

The Brent Valley was negotiated by the Wharncliffe Viaduct, a brick structure with eight semi-elliptical arches of 70 ft. span, supported on twin hollow piers. It is about 900 feet in length.

The River Thames at Maidenhead formed a more difficult problem, for it is about a hundred yards wide at the point where it had to be crossed. Brunel decided on a bridge having two main spans of 128 ft. of semi-elliptical form, with a rise of only 24¼ ft., and four brick approach arches at either end.

Maidenhead Bridge is noted for the fact that it possesses the longest—certainly the flattest—spans ever carried out in brickwork. The flatness of the spans caused a good deal of criticism, so much so that the contractor became alarmed and asked to be relieved of his contract. He was assured by Brunel himself, who showed him geometrical diagrams, that his fears for the safety of the bridge were unwarranted, and the work went on. Brunel's calculations have been amply justified by the bridge having carried steadily-increasing loads for ninety years, and when the width of the bridge was doubled in 1893 the new construction was carried out on precisely the same lines as the old.

Brunel was not so fortunate with the Somerset Bridge over the River Parrett at Bridgwater. This masonry arch of 100 ft. span was designed, and actually constructed, with a rise of only 12 ft., that is to say, half that of Maidenhead. This was begun in 1838 and finished in three years. Shortly afterwards, an outcry arose owing to the obstruction to the river navigation due to the presence of the centering, which Brunel had not ventured to remove. It was not until 1843 that he reported that "the movement of the foundations has continued and under existing circumstances, it is sufficient that I should state that, in compliance with a resolution of the Directors, measures are being adopted to enable us to remove these centres immediately at the sacrifice of the present arch". Six months later the directors stated that a most substantial bridge had been built over the River Parrett without the slightest interruption of traffic.

This "substantial bridge" was a timber arch in one span—said to have been the largest timber arch in the country—and it remained in service for sixty years.

According to the original scheme, the high ground between Twyford and Reading was to be pierced by a tunnel, but a cutting, known as the Sonning Cutting, was substituted, of over two miles in length, and varying in depth from twenty to sixty feet.

The line from Paddington to Maidenhead was opened in June, 1838, and it is recorded that locomotive performance was satisfactory, trains of 80 tons and upwards being drawn at speeds from thirty-eight to forty miles an hour.

By the end of June, 1841, the whole length of the Great Western line was opened from Paddington to Bristol.

The stretch of line from Wootton Bassett to Bath included by far the greatest engineering achievement on the railway, the Box Tunnel, which is 1 mile 7 furlongs in length and cost £100 per yard to drive.

Box Tunnel was by far the longest railway tunnel of the time. Like other tunnels built for broad gauge traffic, it is 30 ft. wide at the spring of the arch, and the crown is 25 ft. above the rails.

To ensure good ventilation in the tunnel, Brunel sank six shafts of 30 ft. diameter, and from 70 to 300 feet deep. It is said that on the 9th April, his birthday, the sun shines right through Box Tunnel, though whether Brunel ever intended this to occur is not known.

Some idea of the speed attained in the early days of railways will be realized by mention of the special train which brought Sir Robert Peel and Lord Stanley from Paddington to Slough (18½ miles) in 18 minutes; while the Duke of Wellington, who had taken reluctantly to rail travel, did the journey soon afterwards in half a minute less. Many would like to know what he thought of the "going".

From the first, Brunel was a great believer in speed—"The public", said he, "will always prefer that conveyance which is most nearly perfect, and speed, within reasonable limits, is a material ingredient in perfection of travelling."

How the Great Western Railway was destined to extend is well known, largely due to Brunel's foresight.

To quote from an address by the late Sir James Inglis:—

"Brunel's idea was that the Great Western Railway should effectually and permanently secure to itself the whole trade of the south-west of England, with that of South Wales and the south of Ireland, not only by a forced monopoly, which could never long resist the wants of the public, but by such attention to these wants as should render any competition unnecessary and hopeless."

The Bristol and Exeter Railway, 75 miles long, received its charter in 1836, and the line was opened throughout in 1844, and under an agreement was operated by the Great Western Railway Company until 1849, from which time it was independent, although working in conjunction with the Great Western, with which it finally amalgamated in 1876.

The line to Plymouth was opened in 1848. The Torquay branch was also completed in that year. Thirty years later the South Devon Railway was taken over by the Great Western Railway Company.

The line from Swindon to Neyland—the old South Wales line—was opened in 1856; all these, with other branch lines, having been constructed by Brunel.

The section of line from Cornwall Junction to Truro was completed in 1859, and that from Truro to Penwithers in 1863. The Falmouth branch was also completed in 1863.

The Broad Gauge

Brunel recommended to his directors, at their meeting in October, 1835, the construction of the railway to 7-ft. gauge—to be exact, 7 ft. 0¼ in.—which, he contended, would allow the carriages to be placed between, instead of over the wheels, and thereby increase their steadiness by lowering the centre of gravity. He, of course, had in mind the advantage a wide gauge would give for the construction of powerful engines.

His proposal agreed to, Brunel made use of timber instead of stone blocks as the supports for the rails, support being given by heavy longitudinal baulks, to which bridge section rails were bolted without the interposition of chairs. At intervals the longitudinal timbers were connected by cross pieces, known as transoms, to keep the rails the correct distance apart. This was, in effect, a reversion to the method used for the original wooden tramways.

The railways designed by Brunel were distinguished from those in all other parts of the country. In most railways, the distance between the inner edges of the rails was 4 ft. 8½ in., known as the narrow gauge.

It may not be generally known that at the time George Stephenson introduced the locomotive engine, the gauge of the lines had been already fixed, as being that of the old wooden tramways on which ran the country carts in the North of England, and in the construction of the Stockton and Darlington Railway (1821–5) he saw no reason to depart from the gauge already adopted. The Manchester and Liverpool Railway (1826) followed the same course, also the Grand Junction and London and Birmingham Railways.

Brunel did not, of course, expect that the difference between the gauge he suggested and that of other lines would lead to inconvenience, but subsequent events proved that he underrated this inconvenience.

The battle of the gauges raged in 1845. All railways north of Wolverhampton were laid to the narrow gauge. By 1861 the number of narrow gauge lines had so increased that there was no longer any hope of extending broad gauge.

The Great Western had acquired existing railways giving them access to Birkenhead, Manchester, etc., and were thus compelled to abandon broad gauge.

The transfer from broad to narrow gauge took place in 1892. The Committee on Uniformity of Gauges, had been appointed in 1846, just forty-six years before the final abandonment of the broad gauge.

The Atmospheric System

Brunel was very interested in the atmospheric system, which had been tried out at Wormwood Scrubbs, Croydon, and Dalkey, in Ireland.

Under this system, a cast-iron pipe-line, about twenty inches in internal diameter, was laid between the rails. The pipes had a continuous longitudinal slot along the upper side to enable an arm connecting an internal piston with the vehicles to be moved to travel along it. The slot was closed by a leather flap. The piston was attached to the forward end of a long frame, the arm to the rear end. An arrangement of wheels on the frame pushed up the flap in advance of the arm.

On air being exhausted from one end of the pipe, the piston was driven in that direction by atmospheric pressure, hauling the vehicles with it. (See folding plate facing page 114.)

This system was condemned by Stephenson as being uneconomical on steep gradients. Brunel held the opposite view, and strongly recommended the adoption of the atmospheric system over the entire length of the South Devon Railway. The directors accepted Brunel's recommendation, and steps were taken to equip the Exeter–Newton Abbot section. (See Photo 2.)

The pipeline was equipped with pumping stations at intervals of about three miles.

When a train was due, the engines exhausted the air, each ceasing to pump as soon as the train had passed. Owing to lack of telegraphic installations, preliminary pumping often went on for a long time when a train happened to be late.

On the whole, the system at first worked very well. From its inception, 790 trains had kept to time. The passengers were pleased by the smooth motion, the freedom from dirt and smoke, and the good speeds attained. The speed on one occasion reached 68 miles an hour with a train of 28 tons. (Average speed 64 m.p.h. for four level miles—35 m.p.h. for 100 tons on same four miles.)

Defects, however, soon made themselves apparent. The cupped leathers used to render the piston airtight were quickly destroyed by contact with the inlet and outlet valves at the ends of the pipe sections at stations.

Under the influence of heat, wet and frost, the leather valves, upon the air tightness of which the whole success of the system depended, deteriorated, and, in spite of the application of oil and soap, became stiff and rotten. Further deterioration was caused owing to the tannin in the leather reacting on the iron with which the valve made contact, and rendering the material tender and easily damaged by the piston arm.

Cost of haulage was nearly treble what it would have been with locomotive power, owing to leakage of air.

The failure of the atmospheric system was a great blow to Brunel's reputation. It hit him financially, as he had invested a good deal of money in the apparatus.

Bridges over Severn, Wye and Usk—Landore Viaduct—Cockett Tunnel

The chief engineering works which Brunel had to undertake in connexion with the original South Wales main line were: bridges over the River Severn at Gloucester, over the River Wye at Chepstow, and over the River Usk at Newport; the Landore Viaduct near Swansea; and a tunnel at Cockett.

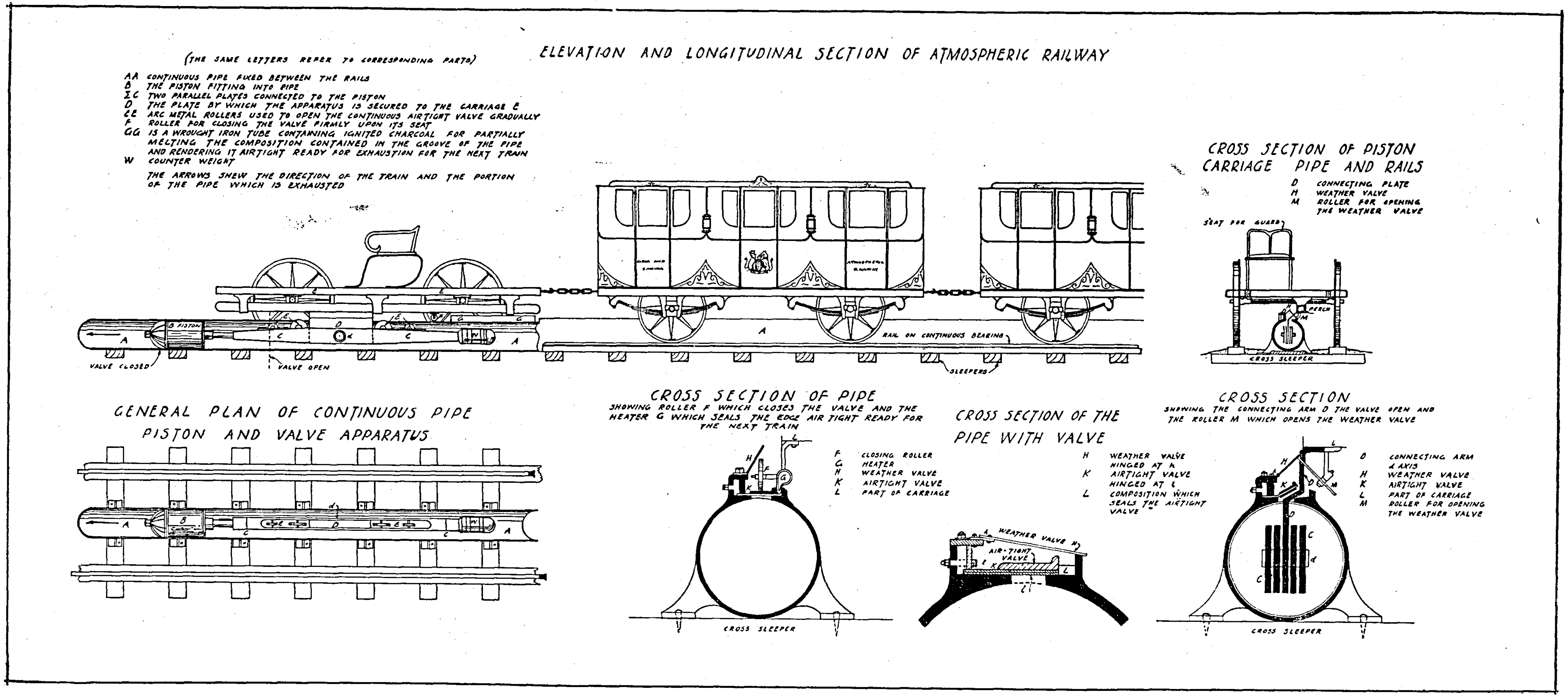
Chepstow Bridge was the most difficult of the three bridges. At the point where it stands, the left bank of the River Wye rises to a height of 120 ft., whereas the opposite bank slopes gently towards the water.

A headway of at least fifty feet had to be left for navigation. In consequence, the bridge had to be approached at one end by a cutting in the cliffs and at the other by a high embankment. The space to be bridged was 600 ft., that is to say, river span of 300 ft. and three land spans of 100 ft. each.

As the railway has a double track, for each line was constructed a separate main truss, each truss consisting of a horizontal tube, 9 ft. in diameter, and connected with the girder carrying the line by suspension chains and upright standards. The first truss was assembled on the river bank, tested, and taken to pieces, after which the tube, with parts of the suspension chains attached to it, was floated into the line of the bridge, and placed in position by powerful tackles. The bridge was opened for one line in July, 1852; the second truss was finished shortly afterwards.

The structure which Brunel built across the River Usk was a timber viaduct of eleven spans of 40 ft. to 52 ft., and a main span of 100 ft. The bridge had almost reached completion when it was partially destroyed by fire, through the ignition of the chemical used to preserve the timber.

Brunel then decided to use three polygonal bowspring iron girders for the main spans in place of the timber trusses. The Usk River Bridge carried two tracks, and three girders (the middle one having twice the strength of the others) were required. These girders were designed by Brunel himself, and his skill in bridge designing was proved by the original girders surviving seventy years of use, at the end of which the engines passing over them weighed twice as much as those employed when the bridge was opened. During the middle


ELEVATION AND LONGITUDINAL SECTION OF ATMOSPHERIC RAILWAY
(THE SAME LETTERS REFER TO CORRESPONDING PARTS)
AA CONTINUOUS PIPE FIXED BETWEEN THE RAILS
B THE PISTON FITTING INTO PIPE
ΣC TWO PARALLEL PLATES CONNECTED TO THE PISTON
D THE PLATE BY WHICH THE APPARATUS IS SECURED TO THE CARRIAGE E
EE ARC METAL ROLLERS USED TO OPEN THE CONTINUOUS AIRTIGHT VALVE GRADUALLY
F ROLLER FOR CLOSING THE VALVE FIRMLY UPON ITS SEAT
GG IS A WROUGHT IRON TUBE CONTAINING IGNITED CHARCOAL FOR PARTIALLY MELTING THE COMPOSITION CONTAINED IN THE GROOVE OF THE PIPE AND RENDERING IT AIRTIGHT READY FOR EXHAUSTION FOR THE NEXT TRAIN
W COUNTER WEIGHT
THE ARROWS SHEW THE DIRECTION OF THE TRAIN AND THE PORTION OF THE PIPE WHICH IS EXHAUSTED
VALVE CLOSED
VALVE OPEN
RAIL ON CONTINUOUS BEARING
SLEEPERS
CROSS SECTION OF PISTON CARRIAGE PIPE AND RAILS
D CONNECTING PLATE
H WEATHER VALVE
M ROLLER FOR OPENING THE WEATHER VALVE
SEAT FOR GUARD
PERCH
CROSS SLEEPER
GENERAL PLAN OF CONTINUOUS PIPE PISTON AND VALVE APPARATUS
CROSS SECTION OF PIPE
SHOWING ROLLER F WHICH CLOSES THE VALVE AND THE HEATER G WHICH SEALS THE EDGE AIR TIGHT READY FOR THE NEXT TRAIN
F CLOSING ROLLER
G HEATER
H WEATHER VALVE
K AIRTIGHT VALVE
L PART OF CARRIAGE
CROSS SLEEPER
CROSS SECTION OF THE PIPE WITH VALVE
H WEATHER VALVE HINGED AT h
K AIRTIGHT VALVE HINGED AT l
L COMPOSITION WHICH SEALS THE AIRTIGHT VALVE
WEATHER VALVE H
AIR-TIGHT VALVE
CROSS SECTION
SHOWING THE CONNECTING ARM D THE VALVE OPEN AND THE ROLLER M WHICH OPENS THE WEATHER VALVE
D CONNECTING ARM & AXIS
H WEATHER VALVE
K AIRTIGHT VALVE
L PART OF CARRIAGE
M ROLLER FOR OPENING THE WEATHER VALVE
CROSS SLEEPER

'eighties the timber spans were replaced by iron girders on masonry piers. The work of doubling the structure to take four lines of way, necessitated by the increasing growth of traffic, was carried out some few years ago.

The Cockett Tunnel is of interest in that, owing to anticipated movements in the side slopes of the approach cutting on the Swansea side, several heavily weighted compensating arches were thrown across the cutting. This method was also adopted in the cutting at Llansamlet where similar conditions existed.

I will now refer briefly to the timber viaducts in Devon and Cornwall. For boldness of conception these viaducts, carrying the railway across the deep valleys, may be said to stand unrivalled. One of these is shown in Photo 3.

Between Plymouth and Truro there were thirty-four viaducts, of which nineteen had from six to twenty spans and varied in height from 80 to 153 feet.

There were also three on the Falmouth Branch, Carnon, Ringwell and College Wood, all were replaced in the 1930's.

I now come to Brunel's greatest feat of engineering, the Royal Albert Bridge, spanning the River Tamar, at Saltash.

Brunel at first designed a single main span, 850 ft. long, to meet the requirements of the Admiralty that any structure put across the river should give a headway not less than 100 feet for vessels passing to and from the Naval base at Devonport, and not obstruct the fairway unduly.

Eventually, after abandoning a design for a timber superstructure of which the minimum span would have been 300 ft. long, Brunel prepared drawings for a bridge with two main spans of 455 ft. each, and long approach viaducts. Some detailed particulars of the bridge are tabulated.

The Britannia Bridge, built by Robert Stephenson across the Menai Straits, had two spans 460 ft. long; but whereas Stephenson had the advantage of a rock in mid-channel for a central pier, Brunel was confronted by water 70 ft. deep, with a thick layer of mud below it before rock was reached.

In June, 1854, a cylinder, 95 ft. long and 35 ft. in diameter at the bottom, was sunk vertically and allowed gradually to rest on the rock below. The work of filling the cylinder with masonry was started in the early part of the following year. The two great trusses for the main spans consisted of arch shaped oval tubes, 16¾ ft. broad and just over 12 ft. high.

The bridge has been described as a combination of an arch and a suspension bridge, half the weight being placed on the one and half on the other, the outward thrust of the arch on the abutments being counterbalanced by the inward drag of the chains. Arch and chains are connected at eleven points by upright standards, braced by diagonal bars, and carrying the roadway girders.

ROYAL ALBERT BRIDGE, SALTASH

Length	2,200 ft.
Main spans	455 ft. centre to centre of piers
Height centre pier above foundation in river bed	240 ft.
Height of rails above H.W. mark ...	110 ft.
Tubes (in pairs)	17 ft. by 12 ft.
Weight of each main span	1,100 tons
Maximum depth of main span	about 70 ft.
Rise of tubes	28 ft.
Materials:—	
Wrought iron	2,650 tons
Cast iron	1,200 tons
Masonry and brickwork	17,000 cu. yds.
Timber	14,000 cu. ft.
Total cost	£230,000
Painting	
Average period (internal)...	$3\frac{3}{4}$ years
Average cost	£3,270
Paint used	12 tons (four coats)

Robert Stephenson had been assisted by Brunel in the work of raising the great tubes of the Britannia Bridge, and Brunel used at Saltash the method which had proved so successful in that case. The method adopted was to lift each truss from its berth by large iron pontoons and float them into position between the piers. (See Photos 4 and 5.)

One of these pontoons was still in service at Plymouth Docks, up to the outbreak of the 1914–18 war and two were removed from the water in Neyland about 1931, where they formed part of the floating landing stage on the Company's Waterford service, and were also used for the Neyland-Hobbs Point Ferry.

The first truss was removed from the shore on the 1st September, 1857, and under the direction of Brunel himself, drawn into place by steel hawsers. Water having been admitted into the pontoons, the truss settled on to the piers and the pontoons were floated away.

It will be of interest to mention that it is recorded that 40,000 people watched these operations, the occasion having been made the excuse for a general holiday in the neighbourhood.

The truss was raised by hydraulic jacks placed underneath, in lifts of 3 ft., the masonry of the land pier being built up as the truss rose. The rams of the jacks had large nuts on them to prevent any possibility of falls taking place.

The Royal Albert Bridge was opened by the Prince Consort on 3rd May, 1859. (See Photo 5.)

In 1903, the floor system of the bridge was strengthened by addi-

Photo 3.—Walkham Viaduct, Launceston Branch.

Photo 4.—Saltash Bridge. Raising the girders from pontoons.

Photo 5.—Royal Albert Bridge, Saltash.

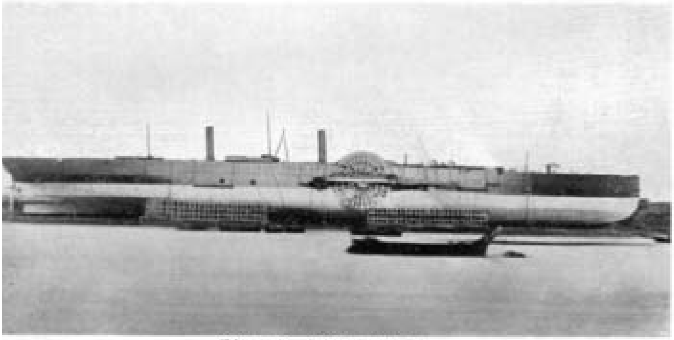


Photo 6.—S.S. *Great Eastern*.

Brunel-A Great All Round Engineer 5 , 6

tional cross-girders at a cost of £7,400 and in 1909, in connexion with the extension of Saltash station loop, the two western spans were rebuilt.

Between 1928 and 1932, the whole of the fifteen land spans were reconstructed at a cost of £19,500 and at a further cost of £6,000 some additional stiffeners were fixed on the main spans, primarily to reduce the vibration of the long vertical members during severe gales. Certain of the suspension pins were also renewed.

During this period a very complete series of deflection and stress measurements were taken and the whole of the main spans exhaustively examined. The condition of the work was such as to occasion great satisfaction to those responsible for its maintenance.

With the object of still further satisfying himself that the bridge was fit for many more years' service, the Chief Engineer Great Western Railway in the 1930s, Mr. Raymond Carpmael, arranged for a series of alternating stress tests to be made at Greenwich Royal Naval College to ascertain whether failure through "fatigue" might be anticipated. During these tests, made on pieces cut from the old girders removed from the approach spans, loads which varied between equal values of pull and push were applied as well as those between unequal extremes, the latter more closely approximating to working conditions.

To give one result only comparable with many—a test piece which when in service would be subjected to a constant stress of 2 tons per sq. in., with an additional intermittently applied one during passage of trains of 5.8 tons, was subjected to alternating loading representing 1.5 tons pull and 9.5 tons push for 15.68 million cycles of application before failure.

I have referred to these tests to indicate Brunel's foresight in design and the selection of suitable materials, which have undoubtedly in the case of the Royal Albert Bridge stood the test of time.

Brunel died on 15th September, 1859, after being ill for some months. He was, in fact, away on the Continent for the benefit of his health at the time of the opening of the bridge, and the only view he had of his finished work was from a truck on which he was slowly drawn across the bridge. Brunel was interred in Kensal Green Cemetery, situated close to the railway which he had served so well.

Apart from his connexion with the Great Western Railway, Brunel was responsible, among other railway works, for the Dublin to Wicklow Railway round Bray Head, and that from Cork to Youghal.

In Italy, Brunel built the Florence to Pistoja Railway. He also laid out a railway from Genoa crossing the Appennines in the direction of Turin and Milan. In India, Brunel was Consulting Engineer for the Eastern Bengal Railway, extending for one hundred miles from Calcutta, though it should be stated that no part of this line was constructed in his lifetime.

The "Great Western" Steamship

During the thirty years of his professional life Brunel was also actively engaged in the accomplishment of undertakings which had for their object the systematic development of ocean steam navigation.

The *Great Western*, the first ship which made regular voyages across the Atlantic Ocean, and the *Great Eastern* and the *Great Britain*, the first large iron steamships, were built under the direction of Brunel. The *Great Eastern* had both screw and paddle propulsion and the *Great Britain* was the first ship propelled by a screw alone.

While it is perfectly true that the *Great Western* was the first steamship built for regular voyages between Europe and America, the first attempt to use steam in the direct trips across the Atlantic was made by an American ship of some 300 tons burden, called the *Savannah* and built at New York. Two voyages only were made by this ship. This was in 1819, and no further progress in ocean steam navigation appears to have been made until the year 1835, when a company was formed in Bristol called "The Great Western Steamship Company".

The *Great Western* steamship was launched in July, 1837.

The double plating of the ship was carried up to 6 ft. above water line throughout the ship except at extreme ends.

The ship left Blackwall for Bristol just after six o'clock on the morning of 31st March, 1838, with Brunel on board. All went well at first, but between eight and nine o'clock a fire broke out. The felt which covered the boilers had been carried up too high and the red lead which fastened it became hot; oil gas was generated, and it burst into flames, quickly setting fire to the beams and under part of the deck.

The ship was run ashore on a mud-bank near Chapman Beacon and efforts made to extinguish the fire. The captain was directing the fire hose against the flames in the fore-hatch when something heavy fell on him from above. Recovering from the blow, he stooped down, and found the body of a man, who was lying insensible, with his head covered to the ears with the water which had collected on the floor. It was not until the man had been hauled up on to the deck that the captain knew that the person who had fallen on him was Mr. Brunel, who was going down to assist the captain by the ladder which reached down from the fore-hatch to the keelson and put his foot on a burnt rung. He fell some eighteen feet. Had Brunel not fallen on the captain he most certainly would have been killed.

The fire put out, the ship continued her voyage to Bristol, which was reached on 2nd April, much to the surprise of the people of Bristol, who had heard that the ship had been completely burnt in the Thames.

A week later the *Great Western* set off for New York, which she reached on 23rd April, having used up three-fourths of the coal she had taken on board.

She left New York on 7th May, 1838, with sixty-eight passengers, and reached home in fourteen days, although twenty-four hours had been lost by a stoppage at sea.

The *Great Western* made regular trips between Bristol and New York until the year 1846. In the early part of the following year she was sold to the West India Mail Steam Packet Company, and became one of their best vessels. She was broken up by Messrs. Castle, of Vauxhall, in 1857, in the presence of Mr. Brunel, who had made the journey to take a farewell of his famous ship.

On 27th April, 1841, Brunel was appointed by the Admiralty, no doubt on account of what he had done in respect of the *Great Britain*, to consider and advise them on the practicability of introducing the screw propeller on H.M. ships. Within a fortnight Brunel was calling upon manufacturers for designs of the engines, which were to be of 200 h.p. with a 4-ft. stroke.

The engine construction was duly begun, but inquiry elicited that though the ship had been ordered it had not been laid down, due to opposition in various quarters. It was not until two years had elapsed since Brunel's first interview with Lord Minto that a suitable ship, the *Rattler*, was launched. As a result of the satisfactory trial, twenty more vessels were ordered and the propeller gradually superseded the paddle-wheel in H.M. war vessels.

In 1851, Brunel was consulted by the Australian Mail Company upon the class of vessels which it would be advantageous for them to purchase in order to enable them to carry out their contract for the conveyance of mails to Australia.

Brunel recommended the obtaining of ships of 5,000 to 6,000 tons burden to avoid coaling elsewhere than at the Cape. Brunel was appointed Engineer to that company, retaining the position until February, 1853. Two ships were constructed during that period—the *Victoria* and the *Adelaide*.

The ideas so gained developed into the construction of the *Great Eastern*, fitted with both paddles and propeller. (See Photo 6.)

The *Great Eastern* was built on the Thames and launched at Millwall on the 31st January, 1858, after an unsuccessful attempt to launch her had been made on 2nd November, 1857. She made her first cruise on 7th September, 1859, just eight days before Brunel's death.

During the years 1860 to 1863 the *Great Eastern* made nine voyages across the Atlantic Ocean and back, being subsequently used as a transatlantic cable-laying ship. As a cable ship her loaded draught reached 35 ft., with a displacement of 32,700 tons.

The history of the laying of the cable is generally well known. The

Great Eastern set off from Valentia on 23rd June, 1865, and the cable was laid more than half-way across the Atlantic. On hauling the cable in to recover a fault, the cable broke and dropped to the bottom of the sea. Three times the cable was partially raised and each time lost. The expedition returned defeated but with the knowledge that ultimate success was certain.

The ship started again in July, 1866, and laid the cable across the Atlantic without any trouble. Strangely enough, soon afterwards the end of the cable which had been lost the previous year was picked up, and the work completed to Newfoundland.

The *Great Eastern* was beached at New Ferry on 25th August, 1888.

These ships, though commercial failures—the *Great Eastern* ruined her owners before she took the water—embodied ideas vastly ahead of their times, and were indications of Brunel's prophetic instinct of the necessities of the future.

Brunel, in designing ships, has left on record that: "I have not hesitated to consult everybody whose opinions I considered valuable, and to bring the result of their opinions in aid of my own and the manufacturer's experience." All the great features of the design were, however, his own.

Sir William Henry White, a former President of the Institution of Civil Engineers, and a famous Naval Architect, said in his Presidential address:—

"In regard to the provision of ample structural strength with a minimum of weight, the increase of safety by watertight sub-division and cellular double bottom, the design of propelling machinery and boilers with a view to economy of coal and great endurance for long-distance steaming, the selection of forms and dimensions likely to minimize resistance and favour good behaviour at sea, Brunel displayed a knowledge of principles such as no other ship designer of that time seems to have possessed, and in most of these features his intentions were realized. To him large dimensions caused no fear."

Brunel often advised the adoption of measures strongly opposed to current opinion and the results obtained have verified his calculations. The conclusions he tried to establish are now so generally accepted, that it is a little difficult to believe that they were ever questioned.

That it was not always plain-sailing, is evident from a letter written by him on 3rd December, 1837, to Mr. Chas. A. Saunders, the General Superintendent of the Great Western Railway.

"In my endeavour to introduce a few—really but a few—improvements . . . I have involved myself in a mass of novelties. I can compare it to nothing but the sudden adoption of a language familiar enough to the speaker, and in itself simple enough, but, unfortunately understood by nobody about him—every word has to be translated—and so it is with my work—one alteration has involved another and no one part can be copied from what others have done. If ever I go mad I shall have the ghost of the opening of a railway walking before me, or rather standing in front holding out its hand, and when it moves forward a little swarm of devils in the shape of leaky pickle tanks, uncut timber, half-finished station houses, sinking embankments, broken screws, absent guard plates, unfinished drawings, and absences of details, will quietly and quite as a matter of course, and as if I ought to have expected it, lift up my ghost and put him a little further off than before."

The dock and pier works which Brunel constructed are at Monkwearmouth, Bristol, Plymouth, Briton Ferry, Brentford and Neyland. In dock work Brunel relied largely on wrought iron for lock gates, with a buoyance allowance to reduce the operating effort.

For shipment of coal at Swansea and Briton Ferry, Brunel made use of that ultra-modern aid to rapid transit, the "container", in this instance a wrought iron box 4 ft. 8 in. cube, holding 2½ tons, four boxes forming a truck load.

Brunel also interested himself in a large number of miscellaneous works and inventions. He was a member of the committee of the machinery section of the Great Exhibition of 1851.

The building was actually designed by Sir Joseph Paxton, with Brunel's support, and embodying many of Brunel's own ideas. The building was afterwards re-erected at Sydenham as that familiar landmark, the Crystal Palace. The water towers, 200 ft. high and weighing 3,000 tons, were his own design. In 1852, Brunel introduced a rifle, with an octagonal shaped inside, having, to quote his own words, "a twist rather more than usual, and an increasing twist, say twice as much at the mouth of the piece as at the breech."

It will also be of interest to mention that two years later, in 1854, Brunel took up the question of the improvement of large guns. I think the following extract from a letter written by Mr. Brunel, in April, 1855, to Mr. James Nasmyth, explains generally his opinions on the question of the construction of these guns:—

"I am trying the effect—as much for the amusement of the thing as with any great expectation—of a cylinder of hardish material wrapped round with iron wire, laid on with a certain amount of tension proportioned to the diameter. Such a barrel ought to be strong—whether practically successful is another thing."

This, in effect, describes the method of construction of modern heavy artillery, which, however, have a second, outer, cylinder or shell shrunk on over the flat wire.

Brunel designed what we now call a "monitor" for use for an attack on Cronstadt and other Baltic ports during the Russian War.

In February, 1855, Brunel was asked by the War Department to design Renkioi Hospital for use in the Crimean War. An experimental ward was erected on the premises of the Great Western Railway at Paddington, and was carefully criticized by competent people.

The plans having been approved, specifications were made, with drawings of the various parts, and tenders were invited for the construction of the buildings. The whole of the materials, stores, etc., weighing together about 11,500 tons, were dispatched in twenty-three ships between 7th May and 5th December, 1855.

Similar hospitals were used by the Americans in their Civil War, also by the Germans in the Franco-Prussian War of 1870. Brunel's description of the details of this hospital show the immense amount of care and thought he expended on them.

From the foregoing, the incredible versatility of Brunel as an engineer will be apparent. It might well be said that he was a shining example of what can be achieved by an "all-round engineer".

In these modern times when the Corps of Royal Engineers has so many responsibilities some specialization is almost inevitable, but it can be overdone. If, therefore, officers can acquire knowledge of as many facets of engineering as they can, the more able will they be in dealing with the ever-expanding reservists who are called up in time of war and the better will they be able to understand the "language" of their particular brand of engineer work.

Five photographs in this article are reproduced by kind permission of the Civil Engineer, Western Region, British Railways, and Photo 2 by Messrs. G. D. Peters & Co. Ltd., Engineers, Windsor Works, Slough, and most of the facts have been obtained from a lecture given by the late Mr. Raymond Carpmael to the G.W.R. (London) Lecture and Debating Society on 20th October, 1932.

The "Great Western" Steamship

Length from fore-part of figurehead to after part of taffrail	236 ft.
Length between the perpendiculars	212 ft.
Length of keel	205 ft.
Breadth	35 ft. 4 in.
Breadth over paddle-boxes	59 ft. 8 in.
Depth of hold	23 ft. 2 in.
Draught of water	16 ft. 8 in.
Length of engine room	72 ft.
Tonnage by measurement	1,340 tons
Displacement at load draught	2,300 tons
Dimensions of Engines	
Diameter of cylinders	$73\frac{1}{2}$ in.
Length of stroke	7 ft.
Weight of engines, wheels, etc.	310 tons
Weight of boilers	90 tons
Water 20 tons to each boiler	80 tons
Diameter of wheel	28 ft. 9 in.
Width of floats	10 ft.

THE "GREAT EASTERN" STEAMSHIP

Extreme length	693 ft.
Breadth	83 ft.
Breadth over paddle-boxes	120 ft.
Depth	58 ft.
Greatest draught of water (corresponding to displacement of 27,400 tons)	30 ft.
Registered tonnage	13,343 tons
Gross tonnage	18,915 tons
Sea speed (with h.p. 7/8,000, increased during short periods to 10/11,000 h.p.)...	14 knots
Designed to carry 3,000 persons easily	
Dimensions of paddle engines	
Number of cylinders	4
Diameter of cylinders	6 ft. 2 in.
Number of boilers	4
Dimensions of screw engines	
Number of cylinders	4
Diameter of cylinders	7 ft.
Number of boilers	6

THE VOLTAGE REGULATION OF SMALL ALTERNATING CURRENT GENERATORS WITH PARTICULAR REFERENCE TO A NEW UNIT EQUIPMENT

By CAPTAIN (E. & M.O.) W. J. JONES, B.Sc., R.E.

INTRODUCTION

THIS paper has been written to review briefly the voltage characteristics of alternating current generators and the various methods of voltage control, and to explain, as simply as possible, the general principles of a new voltage regulating equipment which has lately been adopted as standard unit equipment.

The new device, known as the "Magnicon" exciter will supersede existing equipments and will soon be in service in the field. It embodies several novel features and instruction at tradesman level has not yet covered the new ground. It is, therefore, considered desirable that officers should be familiar with the general principles of an equipment, whose running and maintenance they will have to supervise and direct.

Detailed instruction in this equipment has already been incorporated in the syllabus of the Clerk of Works (E) Course.

Voltage Characteristics of the Conventional Alternator

Unlike D.C. generators of the shunt, series or compound types, the conventional A.C. generator, or alternator, has no fixed voltage-load characteristic. This arises from the effect of armature reaction which causes the excitation to be strengthened when the power factor is leading and weakens the excitation when the power factor is lagging. Accordingly the conventional alternator has a rising voltage characteristic when its armature current has a leading power factor and a drooping characteristic when this power factor is lagging. These effects are illustrated in Fig. 1 and, for a fixed excitation current, an alternator may have any characteristic between the upper and lower curves which represent the limits normally to be expected in practice.

Figs. 1 to 9 are shown on a folding plate at the end of this article.

Methods of Voltage Control

(*a*) *Hand Control*

This involves having an adjustable rheostat in the field of the exciter which is adjusted manually to control the alternator excitation current and hence maintain a steady voltage at the alternator output terminals. Such an arrangement has a limited range of usefulness, and can only be applied where the alternator load is fairly steady and of consistent power factor, e.g., lighting only.

(*b*) *Automatic Voltage Regulators* (*A.V.R.*)

A number of these devices have been developed and have been applied to small alternators such as are part of unit equipment. The Isenthal Voltage Regulator is typical and has been applied to the 27.5 kVA Lister diesel generator.

The alternator output voltage can be maintained automatically within $\pm$ 3 to 5 per cent of a fixed value using regulators of this type. For a single alternator working alone this is often adequate, though some radar equipments require much closer voltage control.

When small alternators are to work in parallel close voltage regulation is very desirable and the action must in general be more rapid than is normally obtained with electro-mechanical voltage regulators if circulating currents between alternator armatures are to be kept within reasonable proportions.

(*c*) *Compensated, Self-Exciting Alternators*

A number of ingenious devices have been developed in recent years to eliminate the exciter, which is an essential part of the conventional alternator, and to embody within the alternator a compensating arrangement to give a reasonably steady voltage at the terminals for all conditions of load current, power factor and load balance.

One such self-exciting alternator has salient poles and relies upon residual magnetism to build up the field which is supplied through metal rectifiers.

Compensation can be achieved in several ways, one of which is to have current transformers in each output cable, the secondary of each current transformer being connected into the rectifiers supplying the field so that the field strength is varied according to the load conditions.

Alternators of this type can be operated in parallel, but are about the same as the A.V.Rs. in respect of voltage variation and rapidity of action.

(*d*) *The Magnicon Exciter*

The magnicon exciter is a two-stage rotating amplifier which is extremely rapid in action and it will maintain the output within $\pm$ 1 per cent of a fixed value.

This type of voltage control equipment has been adopted as standard for unit diesel generator equipment and its action will be described in some detail.

Armature Reaction Excitation

The Magnicon exciter works on what is known as the "armature reaction excitation" principle. This will be most easily understood by considering a two-pole D.C. generator having its commutator brushes short circuited as illustrated in Fig. 2.

Under these conditions a weak field will cause a small e.m.f. to be generated which will establish a heavy current in the short circuited armature conductors.

With this heavy armature current a considerable armature reaction effect is produced distorting the weak field into the vertical plane.

If pole pieces, unwound, were to be introduced in the inter-polar spaces the armature reaction would induce in them polarities as indicated in Fig. 3 with magnetic fluxes then taking the paths indicated. In this diagram the main flux, on the vertical axis, is shown as being three times the "control flux" on the horizontal axis; in practice the main flux may be many more times stronger than the control flux.

This is not an example of "getting something for nothing", as the main field is the result not only of the electrical input to establish the original control flux, but also it absorbs appreciable mechanical power due to the rotation of the armature conductors, carrying heavy currents, in the control field.

Axis of Commutation

From Fig. 2 it will be seen that the control currents in the short circuited armature conductors are commutated on the vertical axis.

Now that the main flux has been established by armature reaction the armature conductors are rotating in this second magnetic field and are having e.m.fs. induced in them as shown in Fig. 4. A load current could now be commutated on the horizontal axis and this would be the output current of the machine. It will be understood that the actions illustrated in Fig. 2 and 4 are occurring simultaneously. Excluding, for the moment, any difficulties, the machine is a two-stage rotating amplifier which will respond very quickly to small changes in the control flux. In stage one the change of control field input will produce a change of armature control currents and, in the second stage of amplification, a change in the main flux will occur producing a corresponding change of load e.m.f. and current. With the amplidyne, a machine similar in principle to that so far described, amplifications of the order of 20,000 to 1 have been obtained. Such an amplification means that a change of 1 watt in the control field input will alter the output by 20 kilowatts.

The Snags

There are two major difficulties arising in the arrangement so far described. Firstly, commutation is not occurring at the neutral axis of either of the magnetic fields; in fact, quite the reverse, as the control currents in the short circuited armature are being commutated at the point of maximum e.m.f. generation due to the main field. Similarly the load currents are being commutated at the point of maximum e.m.f. generation due to the control field.

The second difficulty arises from the armature reaction effect of the load currents. From Fig. 4 it will be seen that this is directed along the control axis and would tend to demagnetise the control field.

Solutions Adopted in the Magnicon

To take the second difficulty first, the armature reaction due to the load currents can be neutralized by suitable compensating windings in the main pole pieces as will be shown later (see page 127).

The solution to the commutation difficulty adopted in the magnicon is to have the armature wound for double the number of poles existing in the control field, or, what amounts to the same thing, to have a half chord winding. This is the distinctive feature of the magnicon exciter, and its effects will now be considered in detail.

The Magnicon Armature Winding and Control Currents

In Fig. 5 if the armature had a normal full chord winding a conductor in a slot at *A* would be connected to a conductor in the slot at *B* so that the e.m.fs. being generated in the two sides of the loop would be in series, and similarly for other loops which would be in series right round the armature with a simple type of winding. With the half chord winding, however, one conductor in slot *A* is connected to a conductor in slot *C* and the other to a conductor in slot *D*. Sufficient of the end connexions are shown to enable the winding pattern to be visualized.

When this armature is rotating in a two-pole field, it follows that all conductors under the influence of one pole will have e.m.fs. induced in them in the same direction, as illustrated. Following the connexions given it will be seen that, in the interpolar spaces, in each armature slot the two-coil sides will carry currents in opposite directions and so produce zero external magnetic effect. The coil sides under the control poles form a solenoid producing the main flux on the vertical axis.

It will be seen that the commutation axis for the upper layer of the armature winding is along PP' and for the lower layer of the winding is along RR'; commutation does not occur along the axis of either of the magnetic fields.

Load Currents and Compensating Windings

Considering the armature rotating in the main field only it will produce e.m.f. and current directions as indicated in Fig. 6. As far as the armature is concerned, Fig. 6 is Fig. 5 turned clockwise through a right angle. It is now clear that the solenoid under the main pole pieces is acting along the control axis and tending to demagnetize the control poles. In order to counteract this tendency, compensating windings, which carry the load currents, are placed in the main poles as shown in Fig. 6. It can be arranged to over or under compensate the armature reaction effect of load currents and in this way the machine can be given a definite characteristic. If there be over compensation the control field will be progressively strengthened with increase of load current giving a rising voltage and conversely for under compensation.

The commutation axes, it will be seen, remain along PP′ and RR' but for the load currents the upper layer of the winding commutates on RR' as against axis PP' for the control currents. Similarly the lower layer of the winding commutates along PP' as opposed to axis RR' for the control currents.

Combined Armature Currents

Let it be assumed that the load currents are five times the strength of the control currents, then the resultant armature currents in magnitude and direction will be as illustrated in Fig. 7. This figure is arrived at by combining Figs. 5 and 6. It will be seen that the compensating winding neutralizes the solenoid formed by the armature conductor under the main poles and the conductors under the influence of the control poles give a resultant solenoid equivalent to that of the control currents acting alone as shown in Fig. 5. The axes of commutation remain along PP' and RR' in the neutral zone between the two magnetic fields.

Applying the Magnicon to Alternator Voltage Regulation

Having discussed the magnicon principle it now remains to see how this machine can be applied as an alternator exciter to give automatic voltage regulation at the alternator terminals. To do this it will first be necessary to examine the construction of the control pole which is to produce the initial weak flux.

Construction and Operation of the Control Pole

Fig. 8 shows the construction of the control pole. The pole is in three parts, the centre part (1) being known as the abutment pole. Around the abutment pole is fitted a copper damping ring (2), which acts, in emergency, as a damping device. Outside this copper ring is the abutment winding (3) and round the whole of each control pole is wound the opposition winding which is electrically connected in series with the abutment winding but opposes it magnetically. These windings are supplied with D.C. through metal rectifiers from the alternator output.

The abutment winding is so proportioned as to produce magnetic saturation in the abutment pole at about half normal alternator output voltage. The opposition winding is proportioned so that at normal working voltage it will produce a total flux in the whole of the control pole slightly less than the abutment pole flux.

Due to the larger area on which the opposition winding acts, the flux density it produces is much lower and, in the working range, variations of applied voltage produce linear variations of opposition flux while the abutment pole flux remains substantially unaltered. This is illustrated in Fig. 9 and it will be seen that at normal voltage there is a small resultant flux. This flux enables the exciter to produce the load current which is the alternator excitation current.

Circuit Diagram and Action of Alternator with Magnicon Exciter

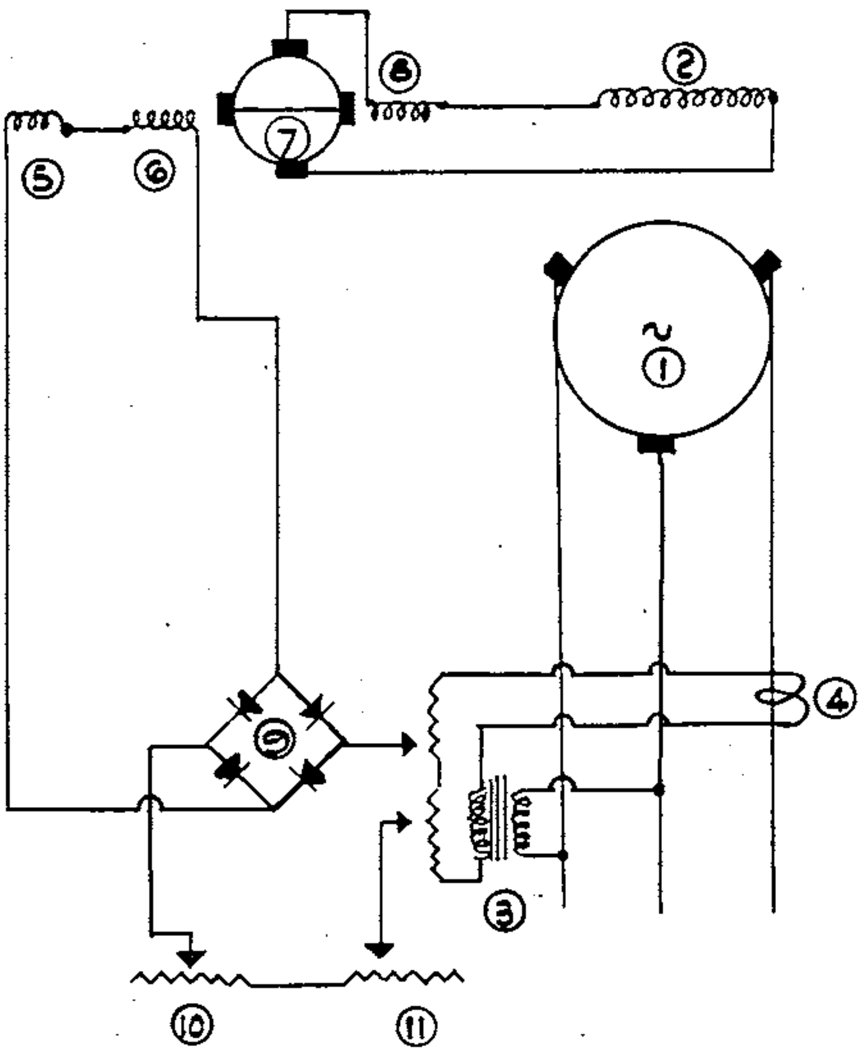
The complete circuit diagram is shown in Fig. 10. A p.d. proportional to the alternator output voltage and influenced by the power factor is applied to rectifiers (9) via the pressure and current transformers (3) and (4).

A fall in the output of transformers (3) and (4) results in a weakening of the opposition flux due to the opposition winding (6) while the abutment flux is unaltered.

This produces an increased flux, *A A* in Fig. 9, the exciter output current is increased and the alternator output voltage is restored. Conversely, an increase of output from transformers (3) and (4) results in an increased opposition flux so that the working flux from the control pole moves to *B B* in Fig. 9, the exciter output is reduced and the alternator voltage is restored to its correct value.

The action is very rapid and the alternator output voltage is maintained within $\pm$ 1 per cent of a value determined initially by means of the manually controlled resistance at (11).

Referring to Fig. 9, it will be seen that any lowering of voltage from normal down to about half voltage at *C C* will produce a pro-



(1) Alternator Rotor
(2) Alternator Field
(3) Pressure Transformer
(4) Current Transformer
(5) Abutment Winding
(6) Opposition Winding
(7) Magnicon Exciter Armature
(8) Compensating Winding
(9) Bridge Connected Metal Rectifier
(10) Temperature Correction Ballast Resistance
(11) Hand Control Resistance

FIG. 10

gressively increasing control flux. If the voltage falls below *C C* the resultant flux begins to decrease and the alternator output will not be restored. It is at this point that the damping ring functions. Such a fall in voltage is only likely to occur under fault conditions and the damping ring may delay the decay of the flux beyond *C C* while the fault is cleared and thus allow the voltage to be restored.

Conclusion

Of the existing types of automatic voltage regulator the "magnicon" exciter undoubtedly gives the closest control.

The magnicon has no vibrating contacts nor does it rely upon varying contact resistances as do so many electro-mechanical automatic voltage regulators. The only sliding contacts in the magnicon are between the brushes and the commutator. Considering the load brushes, the conditions of working are well understood and these brushes are not likely to give trouble. However, the short-circuited brushes are in a different category. The voltage with which they have to deal is small and should there be any change of contact resistance the magnitude of the control currents for a given control field strength will be altered and upset the general working. With the limited experience available it is difficult to say how serious varying contact resistance can be.

It would appear that regular cleaning of the commutator with a soft cloth should suffice. It is understood that experiments are in hand to produce an automatic commutator cleaning device and such a device would eliminate this difficulty.

Also on the debit side is the fact that the magnicon does not utilize material very efficiently. This is obvious from the fact that half the conductors on the armature are self cancelling in respect of their own magnetic fields. The magnicon exciter is appreciably bigger than the conventional exciter, but probably not bigger than the conventional exciter plus the automatic voltage regulator required to do the same job less effectively.

Requiring little maintenance and of inherently robust design, the magnicon exciter should prove eminently suitable for field use.

The object of every electrical engineer is to supply electrical energy to the consumer at a substantially constant voltage; the introduction of the magnicon exciter, whilst making a notable contribution to current practice also marks a substantial advance towards this desirable goal.

Acknowledgements

The author wishes to express his thanks to Lieut.-Colonel R. A. Lindsell, M.C., R.E., for reading early drafts of this article and for making several valuable suggestions. Thanks are also due to Major D. I. Sinclair, R.E., for assistance in reducing some technical difficulties.

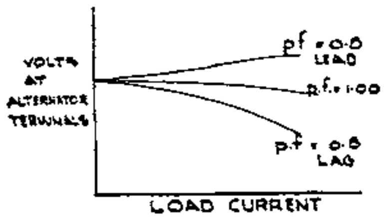


FIG 1

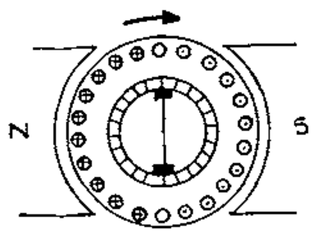


FIG 2

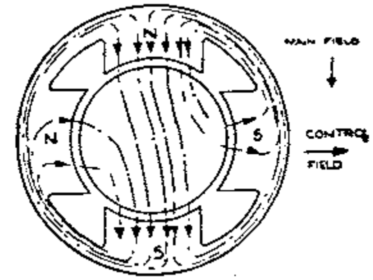


FIG 3

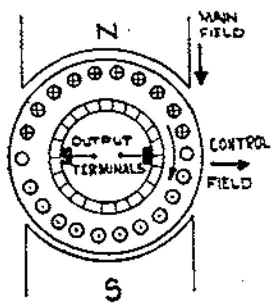


FIG 4

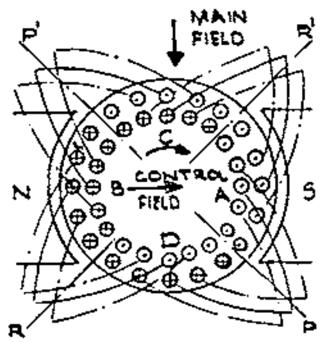


FIG 5

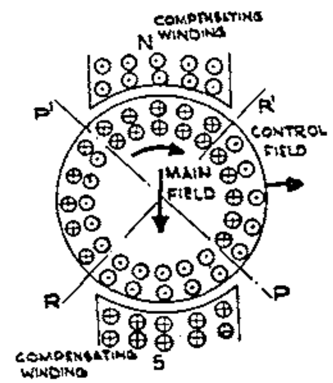


FIG 6

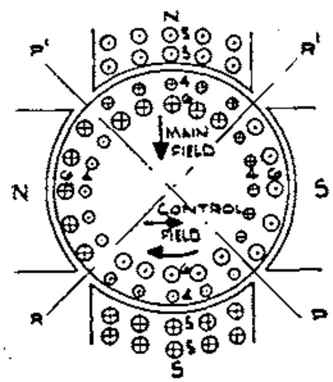
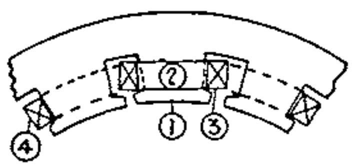


FIG 7



1 : ABUTMENT POLE
2 : COPPER DAMPING RING
3 : ABUTMENT WINDING
4 : OPPOSITION WINDING

FIG 8

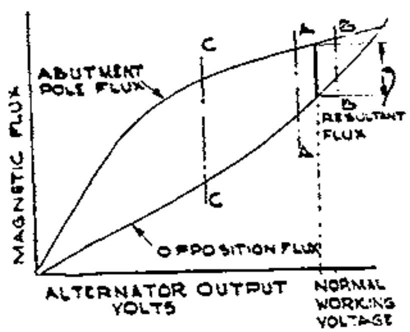


FIG 9

DEFENCE IN THE HOME AGAINST THE TERRORIST

By BRIGADIER I. SIMSON

Editor's Note.—The writer spent six months in Kenya, in the danger area, after the start of the Mau Mau rebellion. Struck by the fact that the European at first was invariably killed without inflicting a scratch on the attackers, he spoke to many residents and wrote for the Press. He was asked by H.Q. East Africa Command to broadcast, and this was done from Nairobi. The script was published in several papers by H.Q. Kenya Police, for cutting out and implementation by individuals in their own homes.

With minor amendments this script is published below at the suggestion of some R.E. officers, in case the ideas prove useful to others who some day may find themselves under similar attack wherever they may then be serving or living.

FIFTY to a hundred years ago, Europeans in several Asiatic countries would find themselves—with or without families—living in areas which had suddenly become dangerous. It is immaterial how or why the danger arose—sometimes by bands of dacoits, thugs, i.e., just robbers; sometimes from racial or religious fanatics; sometimes the attackers came singly, sometimes in bands; often there was collusion by the household servants of the intended victims. Anyway, and naturally enough, the first murder or two in the area was all too easy for the attacker. But once the danger was realized in the area, other civilian families who had gradually developed over many years a regular drill for their own self-protection at home, put this into force immediately. The results were invariably good not only from the angle of self-preservation but also because some casualties were now inflicted on the attackers, even if a particular victim ultimately succumbed to the attacker's weight of numbers. Casualties to the actual attackers do more to stamp out terrorism quickly than subsequent follow-up action by armed troops or police after the incident. The terrorist never likes a hard nut to crack. He wants no risk to himself in the individual battle with his intended victim. Any casualties then inflicted are on the real terrorists and not their half-hearted or coerced followers who get involved in the police follow-up later on.

The technique of self-defence in the home has almost been totally lost by the civilian and his family abroad during the last two or three generations. Development of the Social State may well be one reason as we are all too accustomed to let Government "guard" us financially, medically, educationally, physically . . . from cradle to grave, instead of making a real effort to do these things ourselves, as past generations were accustomed to do. How it is possible for Government armed forces to be present in every home if and when the occupant has his individual battle thrust upon him by sudden attack, is not clear! Yet it is fashionable to criticize the Government and its armed forces instead of criticizing oneself for lack of any preparatory action; which should consist of much more than just arming oneself with a firearm and ammunition. By itself, to be armed merely invites attack in order to get possession of the firearms, as events have proved in Burma (1932–3), Malaya (1949–55), and Kenya (1952–5). In Kenya, Mau Mau presents the old problem in its latest guise, of living as safely as possible in dangerous areas. This makes it essential to know how to use firearms and to let it be known that you can and will use them very quickly and accurately. Once this is realized in the neighbourhood, your household is far less likely to be attacked. Special classes should be held to make men and women, unaccustomed to firearms, reasonably proficient and not frightened to use a revolver or pistol. These are far the best weapons for self-protection at home. Relatively cheap to purchase, easy to conceal and carry with one *always*, quickest to master and to use, five to ten shots before reloading and accurate enough for the very short ranges (say two to twenty yards) for which they will usually be required (inside the house or in the garden) they are preferable to the rifle, shot gun, or any modern spray gun of machine-gun parentage. If any of the latter are available they are, of course, useful as secondary armament for use by other members of the family. But for daily use to carry about house and garden such weapons are too clumsy, heavy and expensive in first cost and ammunition; and obviously unsuitable for elderly people. Above all they are too slow in use against surprise attack.

The first need in self-defence is, therefore, a good revolver or pistol—self-cocking or not, according to availability or individual preference, but real familiarity with the weapon is essential. Speed in picking it up and snap shooting is of greater importance than great accuracy in target practice. Against surprise attack in the house, accurate aim will seldom be possible. There will often be time only to pick up the revolver, point it at the oncoming intruder and fire at very short ranges using one or both hands to steady the revolver. And here let it be said that complete surprise represents about 95 per cent of any individual (or collective) battle. He who gets in the first heavy crippling blow invariably wins; and all suggestions that follow are largely to reduce the effect of surprise and to give more time to use one's own weapon. In Kenya at first, it was usually about two seconds from the time that the European first realized his danger and saw his assailant rushing at him in the room, to the time he was cut down by panga or by simi. Such weapons are something like the Roman short sword with a blade nine to eighteen inches long. They are used primarily for cutting down bamboo and brushwood and sometimes for a stabbing action in addition . For close quarter fighting they are a good one-handed weapon with either one or two cutting edges according to its main use, weight and balance. With many specialized variations, something like it exists all over the world under various names (kukri, kris, machete, parang, panga, simi . . .). All are now manufactured for the agricultural and jungle needs of the population in many underdeveloped countries, by British or other tool-makers.

Time is the essence of survival in a surprise attack by a man with such a weapon. The literally vital requirement—here used in its correct not exaggerated sense—is to gain more time than two seconds to use your own weapon. Anything that the intended victim can do to achieve this, should be done. So far as the revolver or pistol is concerned it must *always* be carried. Use a belt and holster (left open) when working outside in the garden etc. Remember always that when in the house, your assailant will be far more frightened of you than you are of him. He expects you to be sitting up "waiting for him" on your own home ground—all of which in fact you should be doing. He will be very nervous, very hurried, may not have carried out a thorough reconnaissance—so you have every chance of giving him some surprises too. ALWAYS have your revolver fully loaded (chamber and magazine), with you wherever you go—in bathroom and lavatory as well as bedroom or sitting-room. If children are in the house it is certainly better to keep the firearm at "safe" or uncocked—in fact, probably always so except when going out of the house or moving about inside it. Carry it in the hand when changing rooms (day or night), when first going out to the garden or garage. Keep it on a table alongside you, pointing the right way with butt readily to hand when seated reading, eating, writing, listening to the radio, etc. When sitting NEVER keep it in the holster, in your pocket, under a cushion, in the next room, or without its magazine. All these things have occurred and they have all caused delay and disaster; because your "gun" must be capable of being picked up, cocked, roughly aimed and fired all within say two seconds of your first realization of danger, otherwise it is more than useless. Not only will you personally lose the battle, but your firearm will then be used to murder your friends and others later. This incidentally is also why it is always such a severely punishable offence in such circumstances to have any firearm stolen through lack of proper care. Shoot sitting if you happen to be sitting. The chance of your fumbling the job is greatly increased if you also try to scramble out of a deep arm-chair, etc., as the assailant rushes at you. So much for really quick availability of your firearm, with which you must make yourself completely at home—even the ladies.

The problem now is to increase those two seconds available to use your weapon. In any room always sit facing the "dangerous" door and as far from it as possible. Every few days change your normal position in any room. Never mask that dangerous door with furniture or screen it so that an assailant can creep nearer to you unseen, before his final rush. But between you and that dangerous door put fairly large if flimsy items of furniture; "large" so that they cannot be jumped, "flimsy" so that you can see the door round or through the legs. The attacker cannot now rush you by the shortest possible route. He is forced to twist and turn and is slowed accordingly. Your two seconds minimum has now become perhaps three or four seconds; an enormous advantage which should mean that the defender's revolver or pistol should now with certainty beat the attacker's weapon. This apparently small increase of time if available to counter surprise attack often makes the difference between victory and defeat, literally between your life and your painful death.

When asleep it is still more important to avoid complete surprise. Your bedroom door is locked of course. To prevent the door being opened quietly arrange noisy pots and pans just behind it. To burst open even a flimsy door will certainly wake you but the assailant is then attacking you in bed within a couple of seconds while you are still half asleep. So from time to time vary the position of your bed. Between door and bed put obstacles (e.g., several boards with nails points upwards, two inches apart, open packing cases, suitcases . . .) so that the attacker falls over one line on to the other line of obstacles. Like your bed, the obstacles must be out of direct moonlight throughout the night. Arrange them yourself just before you go to bed; remove them yourself next morning. Thus even your servants do not know. Surprise to any intruder will be complete. This simple *ruse de guerre* has twice saved the lives of people sleeping in tents. Unused doors to the bedroom should be barricaded with heavy furniture. The door normally used can, of course, also be barricaded with heavy and noisy articles.

In bed the loaded revolver or pistol is best kept under your pillow (at "safe" or uncocked) together with a hand torch. If the firearm is a rifle or gun it is probably best kept on the floor alongside. But in the case of any night alarm, never use your torch until you are ready to fire—otherwise you may help the assailant to locate you quicker and before you yourself are ready to argue.

Other points deserve attention. If you live in a lonely area which has suddenly become dangerous it is preferable not to sleep alone in a house, even with a dog. If feasible move to an occupied house before dusk and return to your own home by daylight, taking full precautions both ways and on entering your house. No coloured servants should ever be allowed to sleep in any house occupied by Europeans. Preferably lock them all out at dusk and never give even the most trusted servant a key of the house. Tell him where, when and how to knock (using a code), anything else being taken as "enemy". You must personally take the trouble to let him in next morning for early tea or breakfast after he has spoken; again fully prepared for attack when opening the door. The point here is not whether the servant is in fact reliable or unreliable. Even if he is loyal and absolutely reliable, his choice will be to surrender the key to the terrorists if they come during the night or to be killed himself and/or to have his family killed. And until you and I have been faced with a similar decision let us not be too hard on any servant faced with this problem however loyal he may have proved for years previously. In Kenya the servants were mostly in proved collusion with the Mau Mau; or perhaps in a few cases were forced to enter first to lull suspicion.

Prospective aggressors always make a reconnaissance before planning their attack. Your household may be carefully studied beforehand and therefore it is inadvisable to develop fixed habits in time and place—your stroll in the garden (armed), your bath (taken by daylight), meal times, favourite chair in sitting- or dining-room, position of your bed, going iff and out to work or to the outside lavatory (never after dark) . . . Unavoidable fixed times are the radio news and electricity cuts, if any. Both sometimes occur after dark and are then particularly dangerous, since anybody waiting outside can hear or see them. An assailant may well choose the first confusion of black-out, or your absorption in the news, for his attack. So get candles in and alight before the advertised time of any electricity cuts. Keep reasonably quiet, the radio on low and only when you really want it. Never use it as a perpetual background of noise. Otherwise you (and your dog) are far less likely to hear trouble coming, since bare feet make little noise even when hurrying. Draw curtains carefully before dusk and before you light up. In a lighted room you are a perfect target from outside for bullet, arrow or spear. Leave no chinks in the curtains, so that aiming a firearm is imposssible, or so that your position can be studied from outside prior to attack by entering the house. Never let your shadow remain stationary on a curtain for long, never sit close up even to locked doors or windows owing to risk of bullet or spear. Never permit yourself to be enticed out of the house after dark in any circumstances; never use outside lavatories after dark. If you maintain an outside night watchman, arrange whistle codes every half-hour to prove that he is awake. Never go outside to talk to him; always call him to an unlighted window whence you can talk to him. All too often incidents have proved definite danger by day and night in those first few yards outside the house. If you really have to go out for any reason (e.g., on duty), extinguish lights first, wait fifteen seconds after throwing open the door and always carry your loaded and cocked firearm in the hand for really quick action. Inside a room assailants can usually reach you only one at a time; outside, your chances are far less with possibly several assailants from different directions simultaneously. This, of course, applies by day or night. For these reasons and to reduce incendiary risks, cut down bushes, remove inflammable material stacked close to the house; and cut the branches of any trees which overhang the house itself. Where possible neutralize re-entrants of buildings near exits, with barbed wire etc., to discourage lurkers.

At dusk (and by day as feasible) lock and bolt all external doors and windows. If some are seldom used, lock, bolt, nail or barricade them up permanently. Keep to a minimum the number of external doors required for daily use. All windows should be permanently fitted inside with expanded metal or wire mesh—even chicken wire is better than nothing. In hot countries windows required open for ventilation should be masked so that people inside cannot be watched from outside. Lock up unoccupied rooms completely and examine daily for tampering. Lock not only external doors and windows, but all internal doors on the "safer" side prior to going to bed. NEVER leave any locking up to servants—do it all yourself. Tins with pebbles, hanging from curtains or below windows with wire mesh, help to give audible warning of tampering.

The doors of all rooms (drawing, dining, etc.) should be kept closed when occupied. By daylight and after dark, get servants to knock and speak before entering. A favourite dodge is for the servants to be followed a second or two later by the terrorists. So when your servant enters, always cover him with your firearm—and you are ready for others who may follow. Incidentally the servant's respect for you will increase, the news will certainly get around that you are always ready and so the chance of your household ever being attacked at all will be appreciably reduced. Show yourself to be a very difficult nut to crack—and you are less likely to be attacked.

Dogs often give excellent warning of danger but it is unsound to rely upon them entirely. If you have dogs, one is probably best kept in the house at night; the remainder (if any) should preferably be free to roam outside or perhaps locked up in a near-by outhouse. If any are poisoned take this as a warning of trouble likely to develop shortly and notify the police accordingly and those living near you.

To fit your own house and family conditions, think up other means of reducing surprise by obtaining the longest possible warning. Practise your arrangements in each of the various rooms by getting a friend to "attack" you while seated reading, writing, or eating . . . He dashes at you unexpectedly from the dangerous door with a rolled-up newspaper as weapon. The object, of course, is to adjust details so as to obtain maximum speed in pick-up, aim and firing your weapon and to enforce maximum delay on the attacker round obstacles between door and "slashing distance" of yourself. The former necessitates actually picking up and snapping an empty weapon aimed at the intruder. It is therefore imperative that *both* parties should see for themselves that the chamber and magazine are empty before practice begins! The latter involves adjustment of furniture obstacles between door and the position where family members usually sit, so as not to interfere with sight of the dangerous door by all in the room, yet necessitates the slowest possible route for any intruder. Servants waiting at table, etc., must of course, serve this long way round. When reading the newspaper, always sit so that the eye can catch movement at the door past the edge of the newspaper. Other doors should be locked and bolted or blocked with heavy furniture; so that there should be only one "dangerous" door in use for each room if possible. If any one room has two or more exits which cannot be blocked, avoid using that room.

In conclusion, defence, like charity, begins at home if and when such dangers arise. Personal and family defence at home is your direct and personal responsibility on which no Government and no other person can really help. Every one of the various suggestions made above (which make no claim to being complete) has been used at various times and in various places in the past. A person of either sex who has never used a firearm before can become proficient enough and quite safe with revolver or pistol in two or three hours, spread over several days tuition and practice. To think out, adapt and implement some of the above and your own suggestions to fit your own house, family and surroundings, will also not take more than a couple of hours. Thus these obvious and simple precautions really involve very little trouble and expense; and very little inconvenience though they sound most formidable when written out in full. Do not shirk or let them go by default if and when the area in which you happen to live ever "goes dangerous". Do not disbelieve the danger until the family next door is murdered. Above all never let yourself be laughed out of taking simple precautions just because scoffers accuse you of premature "wind up". These simple precautions may save you and everybody and everything that you hold dear if and when your individual battle is thrust upon you; which is better than your refusal to have taken any action being recorded as another famous last word. This unfortunately has been the case all too often after "incidents" first start to occur, before an "emergency" is officially proclaimed and before the public really get worked up. To put it another way—about £15 and say four hours work is truly a remarkably cheap life insurance for a whole family. Lack of thought and action on simple defence preparations in useful time has always cost our nation dear in war on the individual and also on the collective scale. Preparation should never be classed as "wind up". Look on it as insurance. Organize for the worst but hope for the best, is quite a good motto which has always proved sound in peace and war. Act on it when murders start in an area where you happen to be living or working at the time.

CONCRETING IN THE MONTE BELLO ISLANDS

By CAPTAIN D. E. TOWNSEND-ROSE, R.E.

INTRODUCTION

"CONCRETING" to most people is a matter of shovelling gravel and cement into a concrete mixer in some given proportion, adding a certain amount of water, and then pouring it into the shuttering and letting it set—a very dull business. In the Monte Bello Islands, a considerable programme of reinforced and mass concrete was carried out in connexion with the trial of the first British atomic weapon. No one in the Sapper unit which sailed on the expedition, except for the C.R.E., knew much about concrete. In spite of this, careful attention to the methods of mix design and practical work, now set out in *M.E.* Vol. XIV, produced good results.

The site was isolated, and all stores and equipment required had to be carried in one shipping lift, and that very restricted in bulk and dead weight. Also, because of handling and moving difficulties, all machinery had to be kept small.

Limestone and coral sand, but no beach shingle, were available on the islands. A report on samples collected on the early scientific recce stated: "Concrete made from this material is unlikely to be of good quality, and may be dangerously weak". There was no fresh water, but the sea was within about a quarter of a mile of every site.

Further samples from five suitable sites were taken on the later engineer recce of the islands and sent to concrete laboratories in Melbourne. The samples were crushed and carefully graded $\frac{3}{4}$ in. down and 4×8 in. test cylinders were made, with sea water. When crushed, after seven days curing under fresh water, their strengths varied from 1,240 lb./sq. in. to 1,940 lb./sq. in.

Designs for the major works were completed before the results of these tests were known, and, because of the scientific report, the highest working strength was 750 lb./sq. in. This allowed a factor of safety of only $1\frac{1}{2}$ to $2\frac{1}{2}$, provided we could produce as good concrete in the field as in the laboratory.

An attempt was made to train the sections which would do most R.C. work before we left England, but an extremely wet November and a combination of shortage of officers and too many other jobs at the same time, turned the "training" task into a demonstration of what not to do. As such, it had great value, particularly for N.C.Os.

Mix Design

Although the tests showed strengths as low as 1,200 lb./sq. in. at seven days, the C.R.E. believed that consistent strengths of over 3,000 lb./sq.in. at twenty-eight days could be obtained in the field, giving a more normal safety factor, by using a different mix from that used for the test.

The chief differences in the mix actually used compared with the test mix were:—

	Test mix	Site mix
Maximum aggregate size ..	$\frac{3}{4}$-in.	$1\frac{1}{2}$-in.
Water : cement ratio	0.6–0.7	0.4–0.5
Nominal batch by volume ..	1 : 2 : 4	from 1 : 1.7 : 3.6 to 1 : 1.3 : 2.6

The design was based on the principles and graphs given in *M.E.* Vol. XIV (which had not then reached our regiment), tempered by practical experience of workability and a voids test to decide ratio of fine/coarse aggregate.

The sand at all sites was fine, and it was hoped to be able to give this a better grading by adding the fine portion ($\frac{3}{16}$-in. down) of the crusher output; this was found in practice to contain too much "flour", and had to be discarded.

On the voyage out, the C.R.E. wrote a long and detailed instruction on all stages of the work, from first setting up the quarries to final curing and testing. This, with a very few modifications after a little practical experience with the materials available, gave the guiding principles and most details for everyone involved, from the officer responsible for design and testing to the sapper with shovel or tamping rod, who did in fact produce a concrete as strong as the C.R.E. expected.

Rock Crushing

The crushers used were four Goodwin Barsby 12 × 7 in. machines on iron wheels with screen attached. The reasons for this choice were as follows:—

(*a*) The bulk of the concreting was on two islands six miles apart, therefore two sets of machinery were required.

(*b*) Small aggregate was required, needing two-stage crushing to get a reasonable size.

(*c*) The same machine should be able to crush and granulate to reduce the scale of machines, and to allow the machines to be interchangeable in case of breakdown.

(*d*) Machines were ordered by jaw size through E.S.E., and these particular machines were available and fitted the bill. Goodwin Barsby produced the extra parts to convert crushers to granulators.

(*e*) A further factor was that the machines should be mobile, in one piece, and if possible under three tons. It is now thought that this was a mistake, and larger machines should have been taken, if necessary knocked down for transport.

Work was started on setting up the machines at two sites—one on each of the two islands—as soon as the materials were ashore and labour was available, and each took about a fortnight's work before production of aggregate started. An early start to rock crushing was necessary so that concreting—one of the major items in the programme—could begin as soon as possible. Seventy cubic yards of the aggregate per week from each site was the target, but this was never consistently maintained from either of these two first quarries, fifty cubic yards being nearer the weekly production figure.

Both sites worked on two stage crushing, with the crusher set up slightly above the granulator with a sloping chute or barrow run from crusher to granulator. Some of the crusher product was small enough to use, and was screened out into a hopper, and only the stone over $1\frac{1}{2}$-in. went through the granulator. The difference in height between crusher and granulator was small and they were some distance apart, so two or three men were needed to handle the material between the two machines.

These first two quarries were rather uneconomical in labour, and it was very difficult to keep the machines in full production. A number of lessons were learnt in their operation, and these were put into practice when the third and last quarry was set up in a different area. The lessons were:—

(*a*) To avoid unnecessary shovelling, chutes should be at least thirty degrees to the horizontal, and floored with flat steel sheet (C.G.I. is not as efficient).

(*b*) The key to the set-up was the 19 R.B. fitted with grab, and the layout should be such that the grab can reach, without having to move its tracks or alter jib reach, the stockpile of rock, the breaking area, the granulator platform, the hopper, and the vehicles to remove the aggregate.

(*c*) Vehicles for removing the aggregate should have a single way sweep round to fit in with (*b*) so that sledges do not have to be reversed or pushed sideways. (The islands were largely covered by a soft sand, and steel sledges with about two cubic yard capacity had been made and taken out to be towed behind tractors for load carrying.)

(*d*) It was desirable that the machines could be installed and adjusted so that the larger crusher output could be fed direct by chute into the granulator jaws so that both machines would work to full capacity without overfeeding or choking the granulator.

These factors were fulfilled in the third quarry, and by raising the machines considerably the operating party was reduced to about eight, and considerably greater output was achieved. A structure about eighteen feet high, made of 2-in. tubular scaffolding, was designed to carry the crusher and granulator, with the crusher as nearly above the granulator as possible without preventing the granulator from being lifted out by the 19 R.B. in case of breakdown (the other two quarries by this time having been closed down). The designer had many qualms about carrying such a heavy vibrating load on 2-in. scaffolding, and the structure was braced in every possible direction. Each machine was mounted without its wheels on two 6-in. angle iron "capsills", each of which was welded to eight vertical tubes. As a result of these precautions, vibration was much smaller than expected, and caused no troubles of any sort.

The output from the crusher was divided by the screens into three parts; fines led to waste, $\frac{3}{16}$ to $1\frac{1}{4}$-in. went to the hopper, and over $1\frac{1}{2}$ in. was led by a chute straight into the jaws of the granulator. All chutes were gravity operated, but although an attempt was made to make the hopper self filling, it was still found necessary to spread the aggregate in the hopper by hand.

The principal comments on the operation of quarries were:—

(*a*) Provision of stone for the crushers to crush, either from beach boulders or by blasting, was one of the difficulties. To start with large boulders were broken by compressor drills and hammers, and plugs and feathers, but by the last set up the men had become expert with a sledgehammer, and this was found to be the best and quickest tool, in default of a primary crusher or "sledger".

(*b*) Transport of aggregate was always a headache, and a 3-ton tipper belonging to a small R.A.A.F. detachment in the islands (their only transport), was found to be three or four times as fast as any other method, and made a much neater stockpile at the concreting sites. Unfortunately there was far more aggregate than this one tipper could cope with, particularly as it was by no means new.

(*c*) Control of all stages of the work was of the greatest importance, particularly in watching the grading of the output and wear and consequent adjustment of toggle plates. Good control really depended on the quick eye of the N.C.O. i/c, which was better than any voids test or sieve analysis.

(*d*) If any one operation got behind the others or stopped, the whole production ceased, and the N.C.O. i/c had to watch very carefully that this was prevented.

(*e*) If a quarry was to operate for more than a month or so, time spent in setting the machines up properly, particularly in making height, was time well spent. If a fourth quarry had been required, the crusher and granulator would have been built up even higher, to the full height of the 19 R.B. grab at its working range, and an adjustable chute fitted, which could swing to one side when the hopper was being emptied by the grab. This would save another man in the hopper, and enable the fines to be led farther away by the chute, again saving shovelling.

Batching and Pouring

This part of concreting, which is the final measure of output and which it is only too easy to regard as the biggest part, in this particular job took less than 20 per cent of the total man hours spent on the concrete (not including the production of aggregate). The largest time user was transport of stores and materials to site, closely followed by shuttering.

The concreting gang were both young and inexperienced, and took some time to learn the importance of careful batching and thorough tamping, and a very close watch had to be kept on both these operations.

The stone in particular was very poor, porous, soft, flaky and angular when crushed, and any mix to give a good strength was very harsh and difficult to work. Also the porosity of the stone varied considerably, thereby varying the water content. It was found advisable to soak the stockpile thoroughly the day before pouring.

Cleanliness of stockpiles was another problem. A P.B.S. underlay—the only practicable one with the stores available—was no good with sledge haulage, as it was very soon torn in loading, so the practice was adopted of tipping straight on the ground, and condemning the bottom layer.

Sand bulking had to be watched carefully. Variations of over 25 per cent occurred from day to day, and up to 10 per cent in a stockpile while pouring.

Despite these problems, volume batching was successfully adopted, with 2-gallon cans as water measures, and very consistent mixes and cube test results were obtained.

Four 10/7 horizontal drum Millars concrete mixers were used but, because of the large number of small scattered sites involving small mass concrete foundations, it was never practicable to have more than one mixer on any one job. Some trouble was found with keeping the mixers level, and on one or two occasions a hold-up occurred when a mixer got out of level during the course of the day's pouring and overloaded its engine, the first indication of anything wrong being the stalling of the engine with a full drum of wet concrete.

The mix was vibrated with poker type compressed air vibrators, as well as being thoroughly tamped, but care had to be taken to avoid segregation of the very harsh mix by over vibration or over-wet mixes. The shuttering was mainly prefabricated timber panels, and after two or three uses these warped so much that tight joints were impossible, and over vibration caused a loss of surface mortar, so vibration had to be used sparingly.

Sea water was pumped by Petters and pulsometers through canvas hose to "S" tanks at each site. It was found necessary to strip, clean and oil up the pulsometers at least once a week to prevent excessive corrosion of the inside of the alloy casing when working with sea water.

Pouring was the weakest part of the whole operation. It was done in most cases with a 19 R.B. with a bottom opening ½ cu. yd. skip (issued in lieu of the ⅜ cu. yd. side opening skip requested). The main fault was surface honeycombing due to the following causes:—

(*a*) The size of the aggregate was for practical purposes too large. It was reduced for the last building, which had negligible honeycombing.

(*b*) The mix was too harsh for the vibrators to work behind the reinforcement used. A more workable mix was used on the last building with success, at the cost of more cement.

(*c*) The gradual warping of panels prevented shuttering from being completely watertight, causing loss of surface mortar.

(*d*) Concrete of this quality should have been placed in smaller lifts (not exeeeding three feet) in walls. Emphasis on speed tended to encourage bigger lifts.

(*e*) It took experience and not words to prove to the placers the importance of sound and vigorous tamping. Long hours did not improve workmanship.

(*f*) There were few cases of over vibrating.

(*g*) Skips were too large for the work and tended to encourage too much being placed at once, due to the difficulty of manœuvring the skip in a confined space. They were good for general slab work.

Curing was carried out, but in some cases not as efficiently as could be desired, due to the difficulties of labour, transport, and shortage of pumps and hose. The high cement content of mixes made contraction cracks a real danger; these were found on one site when curing was not as thorough as it should have been.

The large number of minor sites, usually consisting of mass or lightly reinforced concrete foundations with holding-down bolts or other fixings cast in, were done on a rather different system. Tools and materials were taken out to site, usually some way from the nearest track, by tractor and sledge, and a small team went round completing one at a time—excavating, fixing shuttering, fixing reinforcement and fittings and pouring concrete—then on to the next one, and finally stripping the first one. The smaller foundations were hand mixed, but for the larger ones a concrete mixer was set up in a sledge, and towed from site to site by a tractor; in some cases a compressor was also towed out to site, and a vibrator used to assist in placing the concrete. A 150-gallon water trailer carried the water for concrete making, and, after pouring, a layer of sand was put over the concrete and damped down to give some measure of curing.

Testing

A number of different tests were carried out at various stages of the work, to assist in mix design and to check output and final strength.

Regular sand bulking tests were made by N.C.Os.; "voids tests" in 40-gallon drums (very hard work!) and "gin bottle tests" of sand for silt and flour (shaking up a sample of sand in water in a gin bottle, and estimating the percentage of very fine particles which settle on top), were carried out by troop officers, to form the basis of field control. An efficient concrete laboratory, equipped with a cube crusher and a set of sieves and balances was set up in a 160-lb. tent. Sieve tests on aggregate, and crushing tests of 6-in. cubes, were made by the officer responsible for mix design. A summary of some of the cube tests is shown in Appendix "A".

Pressure Grouting

Considerable deep honeycombing was found when the shuttering was stripped from the first building, and a decision was made to carry out some experiments on pressure grouting, to see if the honeycombing could be cured in this way.

No one in the force had any previous experience on pressure grouting, and all the books which mentioned the subject said very little except "call in the experts". However, a "gun" was designed and made from a length of 4-in. Victaulic piping. This was propped at an angle, and the lower end connected via a reducing piece and compressed air hose to grouting pipes let into the wall. The grout was then poured into the top open end, a "free", hardwood, loose fitting piston inserted after it, and the end sealed by a blanking-off plate fitted with an air line to an air compressor.

Test blocks of honeycombed concrete were made, and sealed into wooden boxes with a lining of 2 in. of good concrete with grouting pipes fitted. The grouting gun was tested in these with various grouts, and the blocks later broken open to discover how far the grout would penetrate. As the blocks were made with rapid hardening cement and the grout with ciment fondu, this was easy to see.

As a result of these tests, the most suitable spacing of grouting pipes and the best mixture of grout was determined. Grouting was carried out from one side of 12-in. honeycombed walls, and when the other side was cut away for patching, the grout was found to have penetrated as far as expected. The method may be said to have been successful, but a great time was consumed in making and testing the gun, and in this case the "patching" took about 60 per cent of the man hours required for the original construction of the building. However, cutting out and patching, or concreting with another R.C. skin, would have been slower and plant was not available to tackle it.

Rates of Production

Our over-all production figures may be of interest to others faced with a job of concreting in small buildings and foundations over a very scattered site.

Quarrying and rock crushing varied from 7.7 at our best set-up to 18.1 man hours per cubic yard at the first effort.

All concreting operations including transport of aggregate varied from 29.4 to 43.2 man hours per cubic yard. The higher figure was taken in our earlier jobs where the sites were more scattered. The proportions of time spent were:—

Transport, preliminaries and excavation ..	27 per cent
Formwork	27 per cent
Concreting	20 per cent
Reinforcement (supplied ready bent)	14 per cent
Miscellaneous	12 per cent

Conclusion

The results obtained in the Monte Bello Islands show that it is possible to produce in the field, with ordinary field engineers, poor and unsuitable materials, and salt water, a high quality concrete. In only one case was a test cube below specified strength at twenty-eight days (3,000 lb./sq. in.) and inspection after the trial showed no signs of any failure in any of the buildings that were designed to stand.

All concerned came away from the expedition very much wiser and more confident about concrete than they were before the expedition sailed.

Pressure grouting is not quite such a mystery as it is sometimes made out to be. Our methods were crude and improvised, but they worked.

Appendix "A"

Results of Cube Tests

For each of the four main works, test cubes were taken from one batch out of each pour, and these were normally crushed at three, seven, and twenty-eight days respectively; the three-day test was an early check that the mix was adequate, so that it could be altered, if necessary, in subsequent pourings. The following table gives a representative selection of the results:—

Test No.	Batch in cu. ft.	W/C ratio	Strength at 3 days	7 days	28 days	Remarks
1	1.4 : 2 : 5	0.435	2970	3130	3750	
2	1.4 : 2 : 5	0.435	2700	3290	3570	
3	1.4 : 2 : 5	0.435	3060	3490	4375	
4	1.4 : 2.5 : 5	0.435	3490	3200	4200	More fines added to increase workability
5	1.4 : 2.5 : 5	0.465	2850	3350	3300	More water added with loss of strength
6	1.5 : 2 : 5	0.455	1925	2275	2860	Note (*a*)
7	1.6 : 2 : 4.75	0.435	3175	3300	3620	
8	1.5 : 2.5 : 5	0.405	2575	2400	3500	
9	1.8 : 2.5 : 5	0.43	2850	2850	3900	
10	1.9 : 2.5 : 5	0.415	4200	3680	4400	

Notes

(*a*) The weakness of test 6 is probably due to the concrete used in making the test cubes being taken from the first out of the mixer, which is always wetter than the last out.

(*b*) The gradual increase in cement content is a continuous search for a more workable mix to reduce honeycombing.

(*c*) Tests 9 and 10, though apparently "drier" than the others, were in appearance wetter, as, because of the extra cement, there was more total "uncombined" water in the mix.

(*d*) In the case of tests 6 and 7, curing was very inadequate, as the site was isolated, and transport and pumps in short supply. As a result, contraction cracks appeared. Pours 9 and 10 were adequately cured, and no cracking was found.

(*e*) Some three-day tests appear to be high compared with seven-day tests, but only one cube was tested in each case, and this is liable to produce abnormal figures at times.

A NEW SAPPER BATTLE ORGANIZATION

By COLONEL J. W. BOSSARD, M.B.E.

Editor's Note—This article expresses only the author's personal views and does not take into consideration all the factors affecting the situation. This subject is under active review at the present time and it is hoped to publish another article shortly which will take other points into consideration.

The present article is published with a view to stimulating thought and encouraging other views to be produced.

CHANGES in establishment and organization are extremely hard to achieve. The recent impact of nuclear weapons on the battlefield has called for a revision or streamlining of the division. Included is the Royal Engineers element—the present Field Regiment and the C.R.E.—and it presents us with a golden opportunity to review our existing Sapper organization and modify or change it completely, if we so desire. Is such a change desirable and if so, what form should it take? The following are my views based on experience as a Field Squadron Commander, an Engineer Battalion Commander and a C.R.E. in a theatre where engineers were at a premium—in Burma. Before reading them forget everything connected with the divisional Sapper of today. I suggest we must start with a clean sheet.

What have divisional Sappers to do? There is a goodly list in *Engineers in Battle* that includes:—

1. Make, repair, and maintain roads, tracks, and bridges, in the advance.
2. Water supply.
3. Keep open routes for a withdrawal and carry out demolitions, and possibly a scorched earth policy.
4. Development of obstacles, laying of minefields and booby traps.
5. Minefields breaching, and other assault tasks.
6. Crossing rivers and other obstacles.
7. Airstrips.
8. Engineer and local resources.
9. A thousand and one other jobs.

Bearing in mind the proportion of time that a division actually spends in battle (and this is important if you wish to follow my reasoning) do we need to carry about the world all the paraphernalia and clutter that we do at present. I believe the answer to be "No!" When you have a particular job to do you can draw the appropriate tools and equipment. Why carry Danarm saws, Warsop drills, compressors (that are never large enough in any case for a real compressor job) pumping sets, and bridging, until you are faced with the need for them? They can be kept way back in Corps, or even farther, well out of the way. Accept that, and we are a long way on the road to reducing transport, and increasing mobility!

Do we need tradesmen, and here I refer to plumbers, bricklayers, electricians, engineer draughtsmen, and not field engineers, drivers and plant operators? The Corps spends a lot of time and effort training them—to what end? When you raise your squadron you obtain an establishment of them—so many of this and so many of that. How many are employed at their trade, and for how long in each year? What happens in your first battle when you get 20 per cent casualties? Your reinforcements arrive and bear little or no relation to your trade deficiencies. In no time your establishment ceases to apply and you simply have 250 bodies. Yet we go to strange extremes in this respect. Your corporal must have a top rate in his trade to qualify for sergeant. It takes him six months back at Chatham to obtain it. But your troop and squadron commanders want a top rate sergeant, not a bricklayer or carpenter.

Field engineers are not engineers in the accepted sense of the word. Building a bailey or heavy girder bridge, is not engineering. It is meccano building, dependent on training, practice and teamwork. Any body of men of resource can be trained to it. Occasionally the application of a bridge to a gap presents an engineering problem and its solution is one for the commander—not the rank and file. Doesn't this also apply to other jobs like, say, water supply? What it really amounts to is that the tasks your sappers have to do are remarkably like those listed for the assault pioneer.

From this you will see that I am leading up to a squadron, not of specific tradesmen, but of intelligent, resourceful, and tough men, that can be called on for anything. Remember that on mobilization you get in a wonderfully representative cross section of civil life, and any unit commander of a thousand men can usually find a butcher, blacksmith, organist—anything he wants. Remember too that we are considering divisional engineers, and Corps troops. This may be cutting right across the Corps tradition and the like. If so, are we not faced with a really basic problem. Has the time come to cast off another baby, or divide the Corps into two—one containing engineers and tradesmen, and the other type I envisage, the combat sapper?

Now let me lead up to plant. Industry of recent years has been subjected to a searching analysis—industrial research—and the effects are becoming more and more evident every day. They are excellent. One of the main features of this analysis is time and motion study. Can we apply it to military and field engineering, or for that matter to the service generally? If we did we would not build our load carriers—the present three tonner—with a floor so high that a man cannot step in or out without the use of a ladder, nor can he load anything into it from the ground without immense physical effort. This is but one among many similar examples.

Recently an officer, writing in the *R.E. Journal*, said the difference between an American military engineer and a British one was that the American saw a job and said "How many machines do I want?" and the other "How many men do I want?" I think he hit the nail right on the head. More recently, another said he considered that sappers were becoming too dependent on the machine. Which is right? This is a machine age and no commander is "on net" who, in these days of manpower problems, does by hand what can be done by machine. Surely your question must be "Am I doing this in the most economical way?" Machines can be designed to do almost anything. We now lay mines by machine! Why should we not fence; trench; clear mines; and many other tasks? Many of you will say "Ah! but look how ineffective they are when the weather is foul". My answer to that is "Agreed, but see how effective they are when it's fine". You can change the face of the world in an incredibly short time, with machinery. When it is bad, or machines cannot operate, then the resourcefulness of your labour force is applied. The point I want to make is that machines and labour are complementary and that the divisional Sapper organization must contain a balanced element of each. These elements must be of the highest quality.

Why do we have so few machines and are so inexperienced in their use? I blame a disease in the service that for want of a better name I call the "Modification Bug". Whenever a fine piece of equipment comes off the civilian production line the Army tries it—then "modifies" it! The result is that instead of costing £600 it costs £6,000 and few only are seen as exhibition pieces. Take the new "Champ" with its "Schnorkel" tube. How many "jeeps" go nearer water than that they have in their radiators? Who needs a vehicle to crawl up the side of a house or go in reverse as fast as it does forward? For that matter what driver can do so? Surely all you want is to be able to get off the road and cross reasonable country—not impossible country. If you need a vehicle for arctic conditions or desert ones, then order specials. Don't make them all ubiquitous. The cost becomes astronomical and prohibitive.

In Burma we had 2½ ton 6 × 6 Studebakers, low built with steel bodies that could carry five tons or thirty men each anywhere. They could carry sand, aggregate, a 210 cu. ft. Ingersoll Rand compressor, a D4 tractor—anything—and were fitted with a fine front winch. In my opinion they were the best vehicles with which the squadron was ever equipped. They weren't military vehicles; they came off the American roads—ordinary commercial trucks. Then what happened? They were taken from us and were replaced by jeeps and trailers, that in the Kabaw Valley in the monsoon, where it was impossible to get off the road because of the jungle, bogged down and had to be pulled out daily by Dodge 15 cwts. A type of Studebaker is the vehicle we need—a load and personnel carrier in which we can carry anything.

I suggest we want a Sapper battle organization that contains an adaptable labour force and a highly mechanized element. The problem is—into what shape must it be moulded?

Affiliation will always remain. The smallest group within the division will be at about brigade strength, and presumably there will be three per division, each with armour. Therefore, there must be three squadrons; one per brigade. They are to be the labour element composed of handymen, not tradesmen—tough, intelligent, resourceful, renowned for their physical endurance and ability to "take it", as opposed to their ability to lay bricks. The squadron would consist of three troops of four sections of about one and fifteen; a section capable of undertaking many of the present tasks as a team—a squadron of about 250 strong with the minimum of overheads. This leaves us with no reserve, and I had considered a fourth squadron. I discarded it because if it existed it would be committed, as there are always more than enough tasks to go round. And if the load makes it necessary a second regiment will be given to the C.R.E.

What of plant? It is specialized and I would therefore remove it from the squadron. But I want it within the regiment and, therefore, suggest a Plant Squadron, divisible into three, so that its equipment and operators can be sub-allotted to the Field Squadrons. I would go even farther and put all the M.T. in this Plant Squadron and farm that out also, as required. We would have the operative Field Squadron Commander unhampered by the administration done by the Field Regiment H.Q., and plant and M.T. administered within the regiment by the Plant Squadron. All he would have to do would be to keep his eye on the job. His regimental commander would allot him the M.T. and machines necessary to do the job.

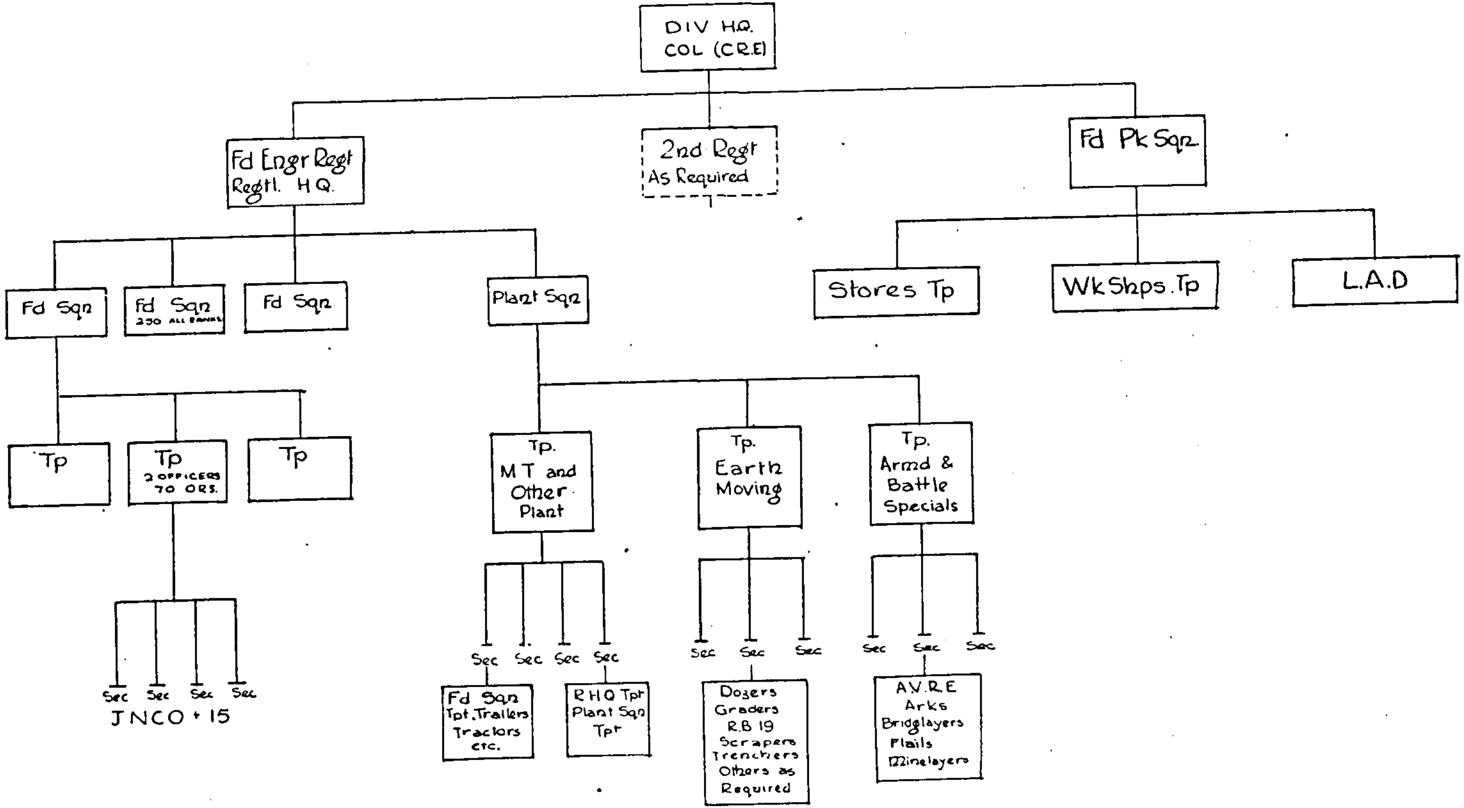
The Plant Squadron I would divide into three troops. The M.T. Troop containing four sections, one for each Field Squadron and one for Regiment H.Q. and its own use. They would be based on two vehicles—the load and personnel carrier already mentioned—on a scale of two, or perhaps three, per Field Squadron Troop, with a trailer that would be the tool cart; and, the other, a small runabout to carry commanders and their wireless. The second would be the Earth Moving Troop of three sections containing dozers, grader, RB19, scrapers, trenchers and others as required. The third would contain what I call the battle "funnies" such as A.V.R.Es., bridgelayers, flails, minelayers, in three sections to facilitate allocation to the Field Squadrons.

The Field Park Squadron I would leave with the C.R.E. but alter its function slightly. What has it to do?—Stores and Workshops. I would, therefore, give it two troops only, the Stores Troop and the Workshop Troop. The first needs no definition. The latter would be a highly mechanized unit, capable of mass production of woodwork and the like. Bridging I would leave out until its use was foreseen. It would mother and house the R.E.M.E. L.A.D.

Lastly, I would carry an identical organization back into Corps, but it would be an Engineer Group of three regiments, a Field Park and the R.E.M.E. Workshops. And its commander would have his own group staff as a complete entity. I wonder how many of you served in G.R.E.F. It was "The General Reserve Engineering Force" that was formed for the major works necessary to get us back into Burma. It was the nearest we have ever been to an Engineer Division and it had an *esprit de corps* second to none. And did it work? It certainly did, in all respects.

Now to sum up. We would have three squadrons of 250 tough resourceful men commanded by resolute officers. Within the regiment would be the complementary plant and transport, to help them with their job. It would not be under their direct command and I suggest that in this way you would most develop the spirit of "getting on with the job". If the machines were there so much the better. If they weren't, the job would take longer. If transport was available they would ride. If not they would walk. But, whatever the conditions, it would be a matter of pride that the job was done, and done well.

SAPPER BATTLE ORGANIZATION



FIGHTING ABILITY AND CONSTRUCTION POWER

By LIEUT.-COLONEL M. L. CROSTHWAIT, M.B.E., R.E.

INTRODUCTION

THIS paper has been prompted by a recent rereading of Major-General Tuck's paper "The Engineer Tasks in Future Wars",[1] and by studying some of the benefits gained by the U.S. Army Engineers from their civil works programme, to which allusion was frequently made in the discussion[2] following General Tuck's talk. General Tuck ended his paper by saying "Whatever the precise nature of engineer tasks in a future war, it seems inevitable that their urgency, their scope, and their magnitude will impose a very severe test on the whole engineer resources of the country . . . Security in war may depend as much on the success in mobilizing and deploying engineer resources as on any other single factor."

There will be few that will disagree with the last sentence. It is a sobering thought. The country's survival in war may depend on its engineering power, and, possibly, on the ability of the Royal Engineers to mobilize, co-ordinate and use that power.

This paper discusses this problem. In particular, it discusses the attitude of the Royal Engineers to this responsibility and whether in the mental approach of the average R.E. officer, and in the traditional place which the Corps holds in the affections of the Army, the right balance has been struck between the combat area and the line of communications; between fighting ability and construction power.

It should be understood, however, that despite subsequent emphasis in this article on construction power (which must be taken to include resources), the stature of the Corps in the Army must ever be based on its fundamental combat rôle.

MEN, MONEY AND MATERIALS

This heading sums up the logistic problems of modern forces. Each Service has an excellent case for justifying greater needs for all three. Within the Army each branch is engaged in a similar tussle. Perhaps the Engineers have a better case than most for demanding a bigger share, but it is unlikely that the traditional proportion allotted to them will be greatly changed. In addition, quite apart from the military problem, intense civil destruction may require extensive aid to the civil power, with the higher direction of essential rehabilitation in the hands of the Army. Ability to make best use of available resources will be at a premium. The speedy and efficient solution of difficult problems will require an exceptional standard of managerial and technical ability. Is everything possible being done to prepare Royal Engineer officers, at all levels, to face these civil and military problems, remembering the limited military resources that will be available to them?

[1] *R.E. Journal* of March, 1954. [2] *R.E. Journal* of June, 1954.

The Engineer Rôle

In short, the task of the Corps is to provide mobility. Mobility has a far wider meaning than that suggested by its traditional context. Engineer construction power must enable the strategists to plan moves with versatility and daring. Air and land forces must be supported, dispersed over the beach operations or through damaged ports. P.O.L. must be supplied in great quantities. Roads and railways kept in operation. For an Army to live and to fight, supplies must be moved and kept moving. The future of warfare may depend on an airlift from supplier to user, thereby removing the need for this massive intermediary logistic effort. However, technical and economic considerations are likely to remove this possibility to the more distant future. Present methods of bulk supply through sea terminals, by pipeline, rail, road, by use of extensive runways, must still be the basis of realistic planning.

It is not only in the forward areas that surprise can be achieved by mobility. Enemy calculations of likely logistic handicaps to be imposed by mass destruction must be confounded. Keeping logistic routes open will be as important, as spectacular and as difficult, as achieving speed and surprise through mobility on the battlefield.

The Engineer Capability

The engineer capability to meet these responsibilities merits careful analysis. Quite clearly it will be taxed to the utmost. Capability will certainly fall short of total requirements. In order to bridge the gap, three main alternatives are possible.

The first is to decrease the commitments. This unfortunately does not lie within the power of the engineer. Enemy action, strategic plans, size of forces to be deployed—these are the considerations that call the tune. Priorities, standards and specifications can be changed and on these the engineers must advise. But, however approached, commitments will remain too high.

Secondly, the engineer force can be increased. As already indicated, the total proportion of engineers within the Army is likely to remain the same. One question, however, remains for the engineers themselves to answer. Is the correct balance being achieved between the engineer fighting and construction rôles? To what extent will circumstances allow constant redeployment of engineer effort between the support and combat areas? If the planned balance is not basically sound, will organizations, training, and perhaps more important, correct assignment of officer talent, allow switching between tasks without great loss of efficiency?

Thirdly, we can increase productivity. By technical skill and superior management, we can endeavour to produce more. Are we certain that the desirability of achieving this aim is sufficiently realized, and that our plans for developing our capability to mobilize and direct the effort of skilled engineers and technicians from civil life, are laid to the best advantage?

Increasing Productivity

Everyone is fully aware of the necessity to use machines and not manpower. (Increased productivity does not, however, begin and end with plant. Quickly applied shovels may often be more effective than waiting around for one dozer.) It is of equivalent importance that if the machines are available they should be used correctly . . . that we act big with big machines; that the bulk of the officers within the Corps are brought up to think beyond the relatively meagre supplies of plant likely to be available to a Divisional or Corps Engineer Regiment. The almost unlimited power of adequate plant managed in the most skilful way must be properly realized. In particular, every engineer officer must be extremely critical of the time factor. Efficient productivity in essence means producing something in a short time. Our sights should be set high as far as timing goes, and the junior officer must ever be made extremely uncomfortable if he fails to meet the deadline reasonably required by his senior. The skilful setting of fine deadlines by seniors and a more unsympathetic attitude to the technical difficulties of the juniors, might make many man-hours available for extra work, owing to the quicker completion of projects.

It is not so much that the difficult should be done at once, but that the Royal Engineer officer should be used to narrow time limits and should feel a sense of failure if, for whatever good reason, he does not report completion in time. Deadlines must be rigid and demanding.

Some Illustrations

The following are two World War II episodes. They are taken from U.S. sources.

"After the capture of Antwerp, the British were having difficulty in removing an obstruction in the Albert Canal, which was to serve as the principal outlet for the Port of Antwerp. A young Royal Engineer officer was in charge of the work. The obstruction consisted of the entire centre section of a three-lane concrete bridge. The officer in charge had planned to cofferdam off the obstruction, pump out, chop holes in the concrete deck large enough to afford a man access to the river bottom and to excavate the river bed through these holes until the obstruction was sunk to a safe depth. As the deck rested on concrete floor beams and girders of some depth, digging would have been slow using short shovels and buckets. To make the picture worse, the cofferdam had failed, and a new start was necessary.

In the meantime the remainder of the canal had been cleared for traffic. It would have taken six weeks to two months to remove this obstruction by this method, even if no further failures occurred.

We prevailed on the British to accept, albeit reluctantly, the loan of some equipment. Using a crane and a large steel billet to break up the concrete, and a clam shell to remove the pieces, the canal was open three days after we started work."

It should be noted that Antwerp is a big port. Even without American equipment, the necessary cranes etc. could possibly have been supplied by a Belgian contractor.

The next illustration concerns the Rhine bridges.

"G" branch of S.H.A.E.F. in planning for the crossing of the Rhine, some eight weeks before the scheduled event, asked the British and American engineer officers attached to the Engineer Division, to estimate how many days would be required for the construction, by their respective engineer troops, of a heavy railway bridge across the river.

The American estimate was thirty days (we doubled the time considered necessary to be on the safe side) and the British seventy-five days. The British opinion was that our estimate was dangerous and unrealistic as the strong current (8–9 m.p.h.) precluded bridge construction from both ends.

Bridge construction by both services started promptly and nine days later the first American crossing was opened to traffic. Thereafter some four additional crossings were thrown across the river before the first British crossing was completed some seventy days after starting.

The British worked from one end only, but the Americans worked *confidently* from several intermediate points."

The Americans possessed more equipment and plant than we did. But the stories are not flattering.

There is a third story, also from a U.S. source, which perhaps has a more important moral still. It is told in the first person.

"Sometimes one just simply isn't aware of what can be done. I always remember an episode during the big Mississippi floods. As a comparatively junior officer, I went out to inspect the damage with one of our bigger contractors. Hundreds of yards of broken levees. The whole area waterlogged. The small approach bridges, by which the damage could be reached, washed out. I knew we had about fourteen days before the next rise in the river would flood the area once again. I was appalled at—to me—the magnitude of the task. I turned to the contractor and asked if he thought much could be done. He hardly troubled to take in the detail. 'Why, sure! You go home and figure out how I get paid.' And of course, it was done. Scrapers, draglines—the whole gamut railed into the area, properly organized and set to work."

That sort of background makes one think big. "Why sure it can . . ." but not by digging out mud through holes in a concrete deck with a spade and bucket; not by insufficiently realizing the construction times that know-how, drive, and organizing ability can make possible. Are we confident that like episodes could not be repeated today?

The U.S. Army Engineers

As already stated, the World War II examples quoted above have been obtained from U.S. sources. In their context they are in no way critical of ourselves. The report from which they were taken was designed to justify the continued control by the Corps of Engineers of their "civil works" programme, which, it had been suggested, should be put under another Government agency. One of the points this report sets out to make is that the potential capacity of the Royal Engineers is reflected by the excellence of their combat record, which was second to none, and yet, on the construction side, by international verdict, the U.S. Engineers were supreme.

"Nearly all British officers were entirely without pre-war experience in handling large engineering construction projects which required planning, organization and use of heavy equipment."

It is not only that the Americans have available more—much more—equipment, or that technically they are more practised than we. The great value of civil works was, and is, that it has been an educator rather than a mere technical improver. It engendered big ideas as to what is possible. It demanded and developed powers of management necessary to run projects worth many millions of pounds. To achieve economy, or to beat the forces of nature, or merely to observe the limits of the fiscal year, the time factor was ever important. The inherent desire to get the job done as cheaply and quickly as possible, meant that good organization and administration of projects by the responsible engineer officers were essential. It was for the technicians to look after the technical and often more straightforward, aspects.

The secret of many U.S. construction achievements has been not only organization but having the right "contacts". Another World War II illustration.

"I was told to be prepared to construct the highways, warehouses, workshops, ports and deep-sea berthing, camps and pipelines required in Iraq and Iran to accelerate the flow of lend lease supplies to British and Russian forces. My sea line of communication would be 15,000 mile in length. There were no local resources of materials, equipment and skilled personnel. Again this was a matter for consultation with the senior experienced civil works personnel, and telephone calls to my friends of many years in civil works districts and divisions. Within three months, the key military and civilian personnel I assembled had completed construction and procurement agreements, established the flow of equipment and supplies to Atlantic and Pacific ports and had the initial ships of personnel and equipment at sea. We landed in Iraq as an integrated construction team and were able to accept every project request . . ."

What will be the time factor, from "M" Day onwards, in a future war? The single Dhekelia project,[1] even with little initial accent on

[1] *R.E. Journal* of December, 1954.

time, overtaxed (manpower restrictions being what they are) the ability of the War Office to produce the basic organizers and planners from its own resources. Will we be in a satisfactory position to assemble the planners and to establish the organizations to undertake the many and immense projects which may be urgently necessitated by atomic destruction or its threat?

The United States Army Reserve Structure

From the construction point of view the Corps of Engineers has another advantage over ourselves. Only about one-fourth of the officer establishment is filled by those with the conventional regular training and background. The remaining spaces are filled by reservists. Generally the latter are made up of officers who saw service in World War II and either elected to stay on, or who were recalled during the Korean emergency and subsequently decided not to start in civil life for a second time. The majority are career reservists, i.e., those who intend to stay a minimum of twenty years on active duty in order to qualify for a pension. Reservists are found in all grades—from Brig.-General downwards, though perhaps the bulk are now Lieut.-Colonels and Majors. While on active duty—in theory at any rate—they qualify for promotions and assignment in the same way as regular officers.

Amongst these officers are a very considerable number who have had extensive experience in civil life—be it in civil, electrical, mechanical, pipeline, etc., engineering. For the most part these officers will have had a far wider theoretical and practical background in their speciality than the average regular officer can hope to have had. The Corps of Engineers thus not only can give officers considerable large-scale construction experience, but there is also, at any given time, a large pool of already experienced officers to call on as necessary. Thus regular officers destined to fill the key positions in the Corps' construction organization have both the opportunity for gaining practical experience and the advantage of working alongside skilled military and civilian engineers.

The Battle Area

The tradition and standing of the Royal Engineers are based on fighting performance. To their concern and chagrin, the U.S. Engineers have great difficulty in being accepted as a true "combat arm". Also our officers in general, look to troop and staff work for success in their careers. Indeed, the extent to which Royal Engineer officers are found in policy-making jobs at every level throughout our Army is the envy of the U.S. Engineers. Finally, the fighting area demands the best. The best it must have, as far as it is in our power to give it.

But quite clearly there has to be a balance between the engineer effort and units allotted primarily to the forward area, or for reinforcing the forward area, and that allotted to maintaining or creating the L. of C. up to the Corps rear boundary. Engineer effort for the L. of C. requires as one of its most important, if not the most important part, engineer officers, with drive, organizing ability, courage, common sense—qualities which also make excellent divisional Cs. R.E., regimental commanders or squadron commanders. Officers will be needed for L. of C. work who combine a sound military background with the ability to appreciate the magnitude of an engineering project, so that direction, command and an exacting attitude towards subordinate technicians can accomplish what is required.

On the other hand, it is the divisions that close the enemy. General Tuck reminded his audience that the old-fashioned way of winning a war by destroying the enemy forces may still be valid. But fighting ability is not always a military end in itself. Another quotation from the American report reads as follows:—

"Unless the Port of Le Havre, which had just fallen, could be opened up, the supply position would become critical. Le Havre was scheduled to be used by the British, but their engineers decided that it was beyond repair for autumn use. The job was assigned to me. My previous contacts in civil works with contractors enabled me to assemble on my staff several able men, who were familiar with heavy port construction. As a result within a short time Le Havre was handling thousands of tons of cargo a day . . ."

It is of little avail for fighting ability to help breach the fortifications if construction power cannot follow up the advantage gained.

New and more machines in the fighting area, dozers, trench diggers, even mechanical minelayers, may be required not only to save Sappers but to give other arms an engineer capability independent of direct Sapper supervision. A great proportion of the best Sapper directive effort may be required farther back.

Field Units and Works

The method of educating Royal Engineer officers, as it has evolved over these past few years, seems excellent. As the first stage in producing not officer engineers but engineer officers, it seems to be the best that we could have hoped for. However, an officer must remember, perhaps more than some of us do, that this technical background is given to the majority of officers as a basis for command and management decisions, rather than for the solution of technical problems.

It is important that the mental attitudes of many officers to the construction (a better word than "works") aspects of military engineering be more objective. If troop and staff duty are considered the important things, and "works" as merely good to have done, we may not be favourably placed if war should come. Unfortunately a routine works assignment is the closest the average officer is likely to come to the U.S. Army's civil works programme. Civil Works is not only responsible for the very large domestic river, harbour and flood control projects. Its field organizations also handle Military Construction, except in those areas directly controlled by a theatre commander. Thus the many and vast deployment programmes, such as the S.A.C. air bases in Morocco, Greenland and within the States have been its responsibility. It is capable of instant expansion to handle any large construction project in case of war. Military Construction, in this sense, does not include "Repairs and Utilities", the branch of the U.S. Army Engineers which is responsible for the functions more typical of our normal works service duties.

Present-day works assignments thus only go a part of the way to conditioning sufficient officers to the type of projects implied in this paper. Up to the present we have been able to rely on a generation of able officers, with India and other overseas areas as their practical background, who have so creditably guided our construction destinies. In the past, too, we have had time to gather our construction ability. It is the future, when the magnitude of engineer work will increase and the time will be shortened, that we must view with concern.

But works, coupled with the long engineering courses, to help fill the gap. The long courses should certainly be encouraged and if possible increased, although they perhaps enhance technical ability rather than the all-important command and management experience. Competent professional training, pointed at engineering management can increase the ability to handle combat tasks, and the keenest "troop" officers need not feel they are getting too far from troops (or staff) if some years are allotted to it.

Relations with Industry

It is very much up to the Royal Engineers to know and know well, the capacity and the key personnel, contractors, specialists and planners of civilian industry. It is we that shall need them rather than the other way round. In fact in peace it is very much a one-way street. Civilian industry needs the Royal Engineers scarcely at all. It is encouraging to learn that one lieut.-colonel is sent every year to achieve this wider aim of getting to know industry. Perhaps we could do with more than one officer per year. Unfortunately, to learn by seeing or understudying is very much second best to learning by having actual financial and managerial responsibility. It is here the U.S. Engineers are so lucky.[1]

We need a great number of Reserve and T.A. and Emergency officers experienced in heavy construction and in operating large projects. Some of these officers should be on the brigadier and colonel

[1]See also the remarks of Lieut.-Colonel J. B. Brown in *The R.E. Journal* of June, 1954 (p. 118).

level so that on mobilization an immediate and intimate liaison is developed with the civil engineering leaders.

A good proportion of Royal Engineer officers must certainly have the ability and, if possible, the experience to understand the requirements of large projects. These officers must learn to think and operate in a big way and to accept responsibility. They must know how to integrate the efforts of civilian trained engineers into the organized engineer support required for large military operations.

Conclusion

In considering this balance between fighting ability and construction power, no apology is made for emphasizing some of our past construction shortcomings and neglecting to mention some of our many important and far-reaching construction achievements. The object has been to stress the immense engineer construction problems likely to arise under atomic conditions, and to examine critically the attitude of the Corps in general, and of many regular officers in particular, as to where organizing ability may be most required.

We will always have a hard core of able officers capable of tackling all aspects of a large engineering task. However, in a future war, such officers may be spread far too thinly, and those of us who mistrust our technical ability, fearing that the knowledge required for even a third-class Cambridge degree has now been submerged under the sands of time, should realize that command and management of large projects does not necessarily require the ability to solve the technical problems, although of course technical ability will be a great asset. It is up to the flexibility of the Corps organization and method of operating (important point this) to supply the right technician at the time and place he is required. It may be required of any regular officer to give direction to his efforts.

In the eyes of the Army, the combat rôle of the Corps must reign supreme. In our own eyes this goal should not be incompatible with each one aspiring to be an engineer officer in the true military sense of the term.

MACHINES AND MEN

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

I FOUND myself standing on the approach to a demolished bridge in the false dawn of a distant city blazing under a grey winter sky. Before that it had been dark; and even now I could scarcely make out where I was, or distinguish the figures standing by me in the gloom. Slowly, groping through the by-ways of my memory, I managed to recall that one was a young captain I had last met in a Territorial Field Engineer Regiment, but the other was a sergeant whom I had never met before. They seemed to have some business here; to build a new bridge I fancied; and had the air of men haunted by memories of an ever-present past. Who I was I did not know, nor why the two should turn to me for guidance in the matters which rested uneasily in their minds.

"Give me enough men, sir," said the Sergeant, "and I'll beat any machine. I know my men. They'll do anything, sir. In the end you've got to fall back on the men."

"Give me the right machine," said the Captain before I had a chance to reply to the Sergeant," and I'll build this bridge by myself. I'll do better, of course, with three machines and some men to help me. I've used machines all my life and I know them as well as I know men. The two together will beat anything you can do with men alone."

"I have no more men," I said to the Sergeant, speaking in my dream as though I had authority over the men and machines working or waiting invisibly around us in the glimmer of that strange dawn,"I have no more men than we had last time, but I have some more machines. The bridges are bigger I am afraid, and the mines are heavier, and the enemy is cleverer. His guns are better too, and his aeroplanes hold their share of the sky. I think you will have to use these machines to help your men."

The Sergeant looked glum. "I know my men," he said, "why can't I have more? Where are all the men, sir? Where are the men?"

I pointed behind us to where a grey cloud rising from the far horizon caught in slowly changing splendour the golden light from the incandescent city far to our front. "That," I said, "is the second bomb on Sturmvier. The Corps Engineer Regiment was in there clearing up after the first. This is a broken-backed war; just as Sir Winston Churchill said it would be in 1953. Do you know what a broken-backed war means?"

"Not enough men," said the Sergeant.

"We must use machines and men," said the Captain.

"Yes," I said to the Captain "machines and men. You know what that means; and now you've got to teach the Sergeant; and after that he's got to teach his men."

* * * * *

Time and space passed with the inconsequence of a dream, until once more I found myself with the Captain, who was watching the Sergeant training his men during an improbable eddy in the relentless cataract of the broken-backed war. I had clearly arrived at an unfortunate moment, for machines and men had somehow stagnated into stalemate, and the Sergeant, beyond even the panacea of being able to vent his fury in sound, had obviously resigned himself beyond redemption to the ultimate triumph of material over mind.

"It won't jump," said the Captain sweetly.

"What do you mean?" muttered the Sergeant, looking at an offending humper with a glare which would have started a chain reaction in any lesser machine and vaporized it on the spot. "I know it ruddy well won't jump."

"You've penned it in," said the Captain. "You've put that transom down with a crane just where you will be needing to move the humper next—and then you've gone and parked that dozer alongside. You can't move the humper now. See?"

"Yes," said the Sergeant, "I see. Won't jump. My men will jump." And then turning to me for help, "Give me some more men, sir. Why can't I have enough men?"

"Look," I replied," on that hillside there. They're building overhead cover for guns. It cuts down the effective burst of the bomb against artillery. Cuts out flash. Gives a man a chance to dive for cover before the tail end of the radiation comes, and before the blast. The rest of your regiment is working on that. You know the Gunners are short handed after the bomb that half caught the A.G.R.A. at Les Salles. The guns were all right the next day, but even the lighter casualties among the men will be a month in hospital. Its a broken-backed war all right. Do you know what that means?"

"Yes," said the Sergeant, resigning himself to the inevitable, "machines and men. But," he added, "the men *can* jump."

The Captain laughed. "Come on Sergeant," he said, "I know the machines aren't grasshoppers. You don't have to make them try to jump though. Have another go and try to think it out better this time. You see," he continued after a pause, "every machine has its own way of covering the ground and reaching the loads it has to handle. Some machines have to move right up to the loads; others can reach them with their jib arms. Men can move much more freely than machines. So freely indeed that you don't have to think much about it. The machines we have can move freely enough, but you've got to think out a movement plan for them. You must leave runways for your cranes to move along, and make sure that your stores are in reach of the crane jib when the crane is on the runway. For humpers, of course, you must leave runways right up to the stores, and also make sure that there is enough room for the humpers to manœuvre."

"That's all very well, sir," objected the Sergeant, "but after you've left all your runways there won't be any ruddy room left over either for the stores or for the bridge."

"Oh no!" said the Captain, "you've forgotten that with your cranes and humpers you can pile your stores. I'll show you." He jumped into the driving seat of an idle humper. "Here's a transom parcel—five transoms—forty man loads. I put it here on a couple of bits of timber packing. Now for another on top of the first, with two more bits of wood to separate them. Here's another, and another. That's twenty transoms, 160 man loads parked in six minutes on a bit of ground twenty feet long by three feet wide. That's half the transoms you need for your bridge and I've left plenty of room for more. It would have taken you quite a while to do that by hand, wouldn't it?"

The Sergeant nodded grudgingly. There was a pause, and then he spoke. "The regiment's awfully busy on those gun positions, sir. You know we could let them have a few men from here all right."

"Not too fast," said the Captain with a smile, "you've got a lot to learn yet. Look! It takes five minutes for a crane and four trained slingmen to unload a parcel loaded truck. That truck has been standing there for forty-five minutes, and your chaps have only just got the first parcel off."

The Sergeant scowled. "I don't know what's wrong with them, sir," he said, "thats a fact. I don't. I've got to have my best men building the bridge. Those four blokes are a bit ham-handed I know, but I thought they would be all right as slingmen. The Corporal is a good bloke too, though he's never done it before. He's from the infantry, sir. You know they're starting to transfer them into the other arms and services to make up our numbers. It's a cushy job up in front now."

The last remarks had obviously been addressed to me. I smiled. "Yes," I said. "Have you seen the last lot of decorations in the Port Operating Regiments?"

The Sergeant nodded. "They earned them too, the poor blighters. Don't say it, sir. I know it's a broken-backed war."

I laughed. "As a matter of fact I wasn't going to say that this time. I was going to say it was a topsy-turvy war as well."

"I can think of some other words for it," said the Sergeant, "but I won't use them now. The Captain's a bit young. You know, sir, I remember going out on a recce with an infantry patrol in the last war. A sergeant and six men it was. Clump, clump, clump they went, right down the middle of the road straight towards the perishing Hun. 'Look, Sarge,' I says, 'you're here to look after me, but if you don't mind, Sarge, I'd rather go down to the bridge alone. You're in the Light Infantry,' says I, 'but no one would ever think it. Haven't you ever been on a night patrol before?' He looked at me a bit sorrowful like and said 'No Corp, we were in the Medical Corps this morning, on ward duties,' he said, 'and we haven't even got used to wearing these perishing boots yet'."

The Captain laughed. "You've said it, Sergeant. The fact is every man has got to know his job. Its dead simple taking parcels out of a truck with a crane, but you've got to know how. You've got to know where to put the crane, where to put the truck and where to fasten the slings. That's all. But if you don't know how . . ."

There was a dull crash and a scream of pain. The Captain moved like lightning round a truck to where a sapper was lying, pinned to the ground by a wicked weight of banded steelwork. We followed. A quick witted operator on a passing humper swung round, edged his forks under the load and lifted it clear, while the Sergeant took the weight on the other side with a handspike. The Corporal retired behind a tree to be sick.

"Broken leg I think," said the Captain, "and maybe a few ribs. But he'll be all right."

The M.O. arrived and the man was taken away on a stretcher.

"That," said the Captain, "is what happens with untrained men. Forty-five minutes to do a two-minute job, and a chap half killed in the bargain. Its not as easy as it looks. You've got to train your men properly. Remember, too, that unloading and handling stores is an essential part of building the bridge. You've got to have a really trained man in charge of this work and trained men working on it with your machines."

"Sir," said the Sergeant to the Captain after what seemed to be a couple of hours, "I don't get the hang of using these perishing humpers on building this bridge. I've got the runways all right now, and my stores unloaded and laid out, but really, sir, the machines seem to do nothing but get in the way of the men, and we just don't seem to get anywhere at all."

"Sergeant," said the Captain, "the men aren't trained. They're trained in bridging all right, but not in working with the machines. They don't know just what the machines can do and what they can't, and, what's more, they don't know how to take the stores from the machines and put them into the bridge." He turned towards the men, whose interest in the machines was disappearing in a fog of unrealized ignorance. "Look there! That panel party has got the humper too close to the bridge, and is having a devil of a job to get the panels off and round into the bridge. If the humper had been stopped a foot farther off there would have been no trouble. There's another thing. That transom party is trying to get the machine to manœuvre the transom right into place. That's asking the machine to do too much. What's needed there is for the men to lay their hands on the transom and give it a push. The men have to learn. Get your men trained and then you'll see the sparks fly. It won't take long."

"Yes," said the Sergeant, "I see now what's wrong. But I couldn't see it at all at first. We all said that there was nothing to working with machines, but I can see now that there's a lot more to it than any of us thought."

"Yes," said the Captain, "men and machines form a team. No team can be any good without training as a team. Your men have only had a week so far; you will need a month before they are any good."

"Sir," asked the Sergeant anxiously, "will there be time for that now? A month seems like a year in this broken-backed war. Sir, we should have trained the men before. Will there be time now?"

* * * * *

I think the Sergeant must have got his time, because a little while afterwards I met him again, as though in a drop scene behind which I could not see.

"Hullo, Sergeant," I said. "What do you make of it all now?"

"I've learnt a thing or two about machines from the Captain, sir, and you're both right. Its machines *and* men for this perishing broken-backed topsy-turvy war. But you've got to know your machines, sir, just as you know your men. This one's a real beauty, but this other, if I may say so, is a real lady dog, sir, with knobs on too. Though she's not so bad really, once she's warmed up a bit." There was a pause, and then he went on. "Do you know, sir, the Captain and I built a bridge by ourselves the other day; with his batman and the mess orderly to put the pins in. It was a proper party, sir."

"Where were the men?" I asked.

"Down on the beach," came the answer.

"Bathing?" I said in surprise.

"Oh no, sir," said the Sergeant, "Pulling the Port Regiment out of the drink. Tidal wave it was, right up over the beaches . . . a hydrogen bomb on a convoy . . . twenty miles out . . ."

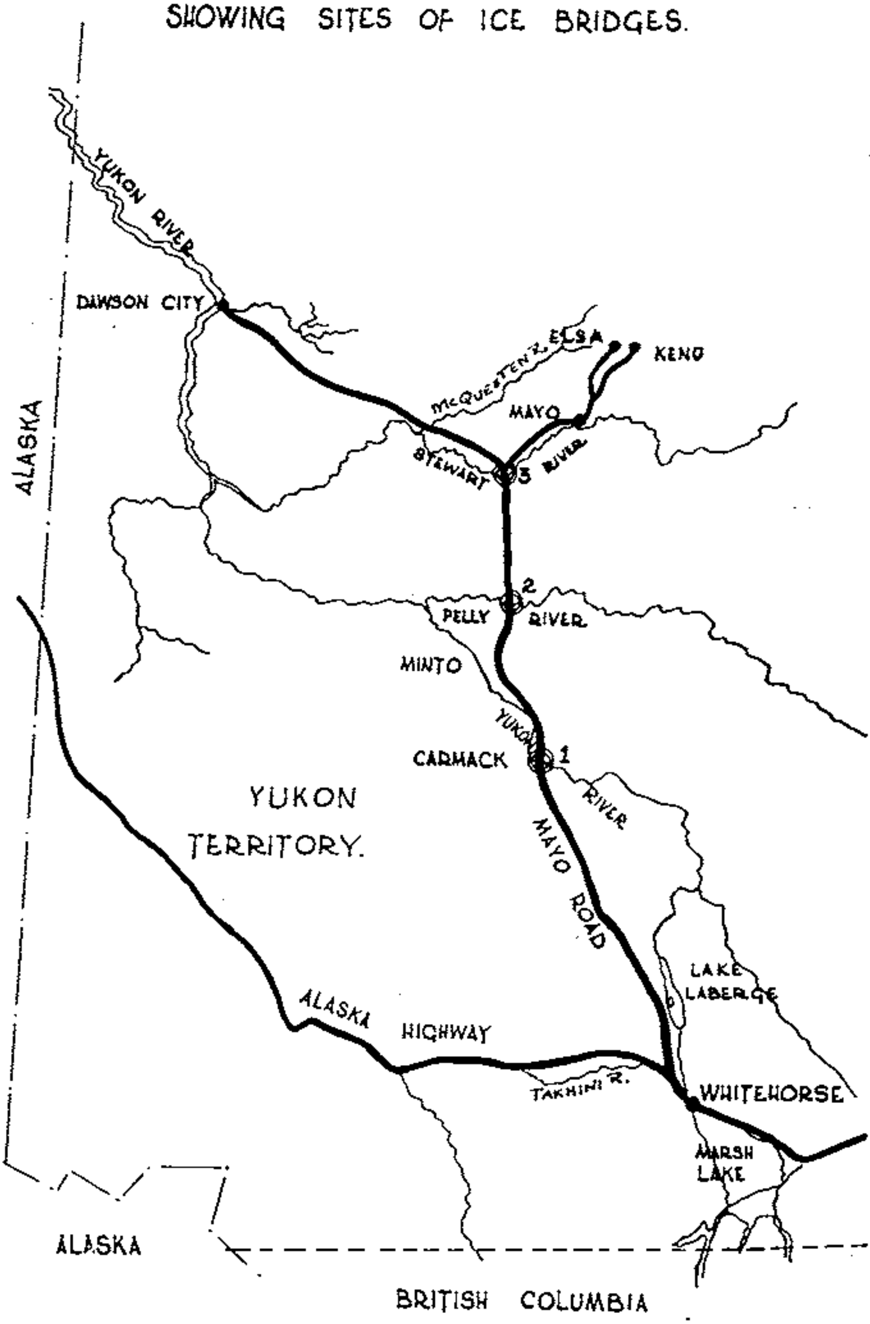
* * * * *

Yes. Then I woke.

I had met the Captain not long before. He had had the experience and right attitude of mind to learn about new machines and new methods, and to pass on his new knowledge and old experience to the Sergeant. I realised too that I had met the Sergeant many times before, by many names. He too would be willing and able to learn, once he saw the need, and provided the right person were there to teach him.

Fortunately the broken-backed war was yet but a shadow on the future. There was still time for the Sergeant to learn, and to teach his men. But the Captain was still in the T.A., and I could but wonder just where, and how, and when the Sergeant was going to learn.

SKETCH MAP OF MAYO ROAD
SHOWING SITES OF ICE BRIDGES.



ICE BRIDGES

By Major P. J. Carson, R.E.

Scope

THIS report covers a description of ice bridges which are constructed and maintained during winter on the Whitehorse to Mayo Road, Yukon Territory.

The aim of the report is to derive information about the ice crossing of rivers in this area with a view to adaptation of the methods used to military construction in similar circumstances.

Introduction

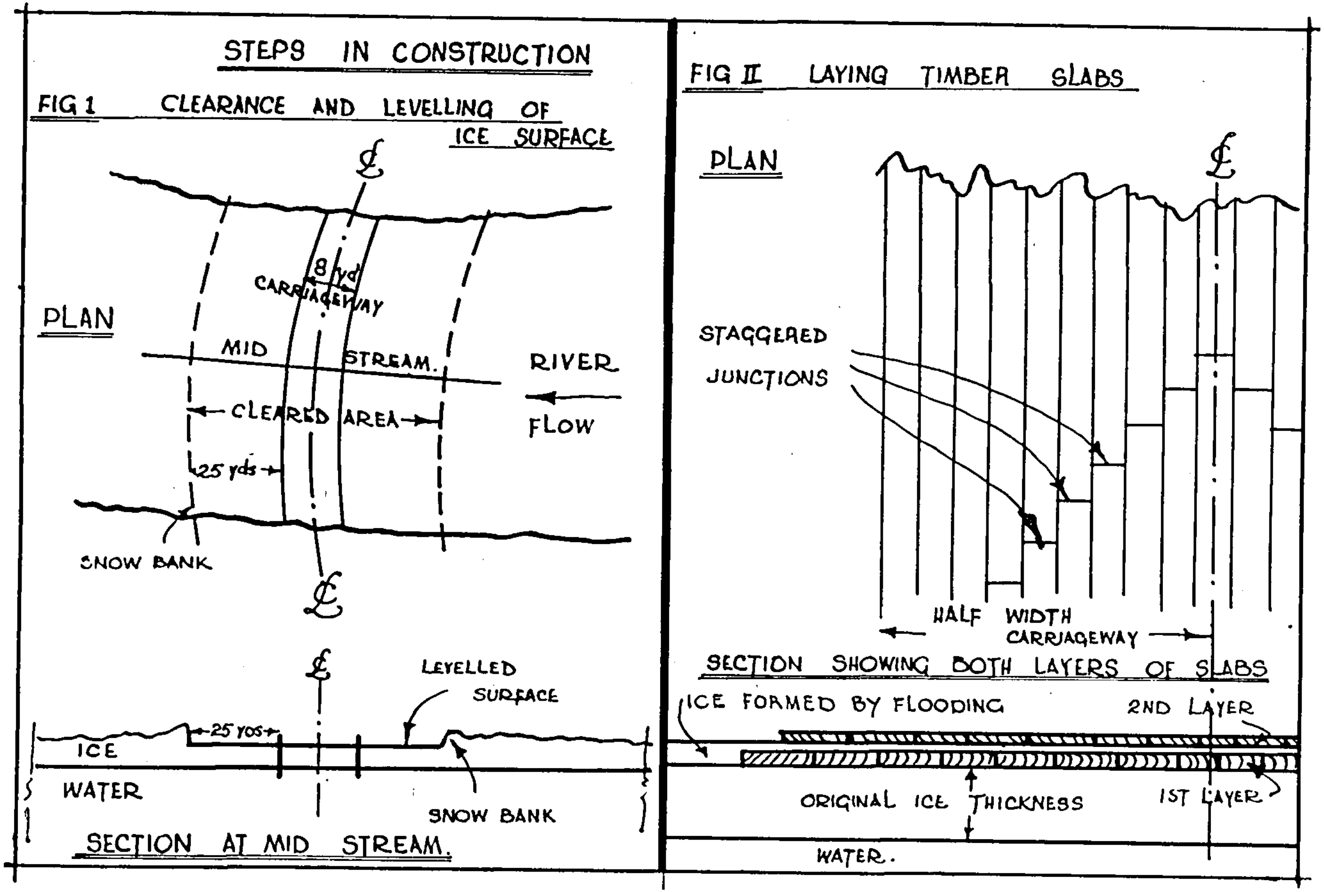
Before going into the description of the crossings, it is useful to relate briefly the reason for and location of the bridges. The sketch map facing this page shows the importance of the road in providing land communication for the Mayo Area and Dawson City. There are also, of course, air and water routes, but the latter is now almost dead with the exception of tourist trips from Whitehorse to Dawson.

The Takhini, McQuesten and Mayo Rivers are the only ones, of greater width than sixty feet, for which bridges have been constructed. The three large rivers, the Yukon, Pelly and Stewart, are negotiated in summer by ferries.

During late October each year the Mayo Road is usually closed, the ferries ceasing operation due to drift ice. As soon as the ice packs downstream and stops moving at the crossing places, road maintenance gangs begin to "construct" ice bridges. These remain in operation until some time during April the following spring and enable traffic to use the road throughout the winter.

The Mayo Road was built by the Federal Government about four years ago and is kept up by joint maintenance between the Territory and United Keno Hill Mines Ltd. This company, operating at present at Elsa on Galena Hill, north of Mayo, is the largest mining concern in the Yukon, much larger than the gold mining industry in the Dawson area. United Keno Hill Mines produce zinc, lead and silver in high grade ores which are refined finally in Southern British Columbia. In 1953 over 12 million dollars worth of ore was mined.

United Keno transport the ore from Elsa to Whitehorse in their own fleet of trucks. The average number of vehicles per convoy during March, 1954, was twenty-two. Two relays work, one travelling


STEPS IN CONSTRUCTION
FIG 1 CLEARANCE AND LEVELLING OF ICE SURFACE
PLAN
8 yd CARRIAGEWAY
MID STREAM.
RIVER FLOW
CLEARED AREA
25 yds
SNOW BANK
LEVELLED SURFACE
25 YDS
ICE
WATER
SNOW BANK
SECTION AT MID STREAM.
FIG II LAYING TIMBER SLABS
PLAN
STAGGERED JUNCTIONS
HALF WIDTH CARRIAGEWAY
SECTION SHOWING BOTH LAYERS OF SLABS
ICE FORMED BY FLOODING
2ND LAYER
ORIGINAL ICE THICKNESS
1ST LAYER
WATER.

south and the other north each night. There are, with other mining or transport companies, at least sixty heavy vehicles moving over the length of the road every twenty-four hours. United Keno transport about 200 tons of concentrates each night to Whitehorse and return to Elsa with freight, food and other supplies. The concentrates travel from Whitehorse to Skagway by train and from thence to Vancouver by boat.

United Keno Hill Mines have, understandably, a great interest in keeping the Mayo Road open. They carry out and supervise the maintenance of the road and construction of the ice bridges each winter. Their aim is to produce bridges as soon as possible after the ferries cease to operate and keep the road open as late as possible into the spring.

It is felt that the experience of the men constructing the ice crossings might be used as a guide for similar military needs. The fact that these bridges are used to further financial gain and that the crossings have been annually constructed over a number of years without serious failure, leads to the conclusion that their methods warrant study. It must be emphasized that all the information given on construction is only approximate, since only limited records have been kept.

Steps in Construction

The choice of site is determined through local knowledge of ice thickness and currents in the river. The approaches have also to be considered. Thus at the Yukon River the ice bridge is about 700 yards downstream, whereas on the Pelly and Stewart, the bridge is at the ferry site.

Once the ice has stopped moving the site chosen for a crossing is levelled off and any snow cleared for about twenty-five yards upstream and downstream of the roadway. The levelling is necessary since broken ice has been flowing in the river before complete freeze-up. (Fig. I.)

The edges of the area cleared are banked up or dammed with snow to prevent too wide distribution of water during flooding. Flooding is commenced to a depth of two or three inches to complete the levelling. The roadway is then "paved" with slabs of timber from a local sawmill. These slabs are placed in a staggered manner in order to obtain some bonding. After the first layer more flooding is carried out to a sufficient depth that the slabs are just covered. The second layer of slabs is then laid. (Fig. II.)

Flooding is then carried out to a depth of one foot to eighteen inches above this, the final depth being between eighteen inches to two feet thicker than the normal river ice. The final six inches is applied only to the carriage way itself.

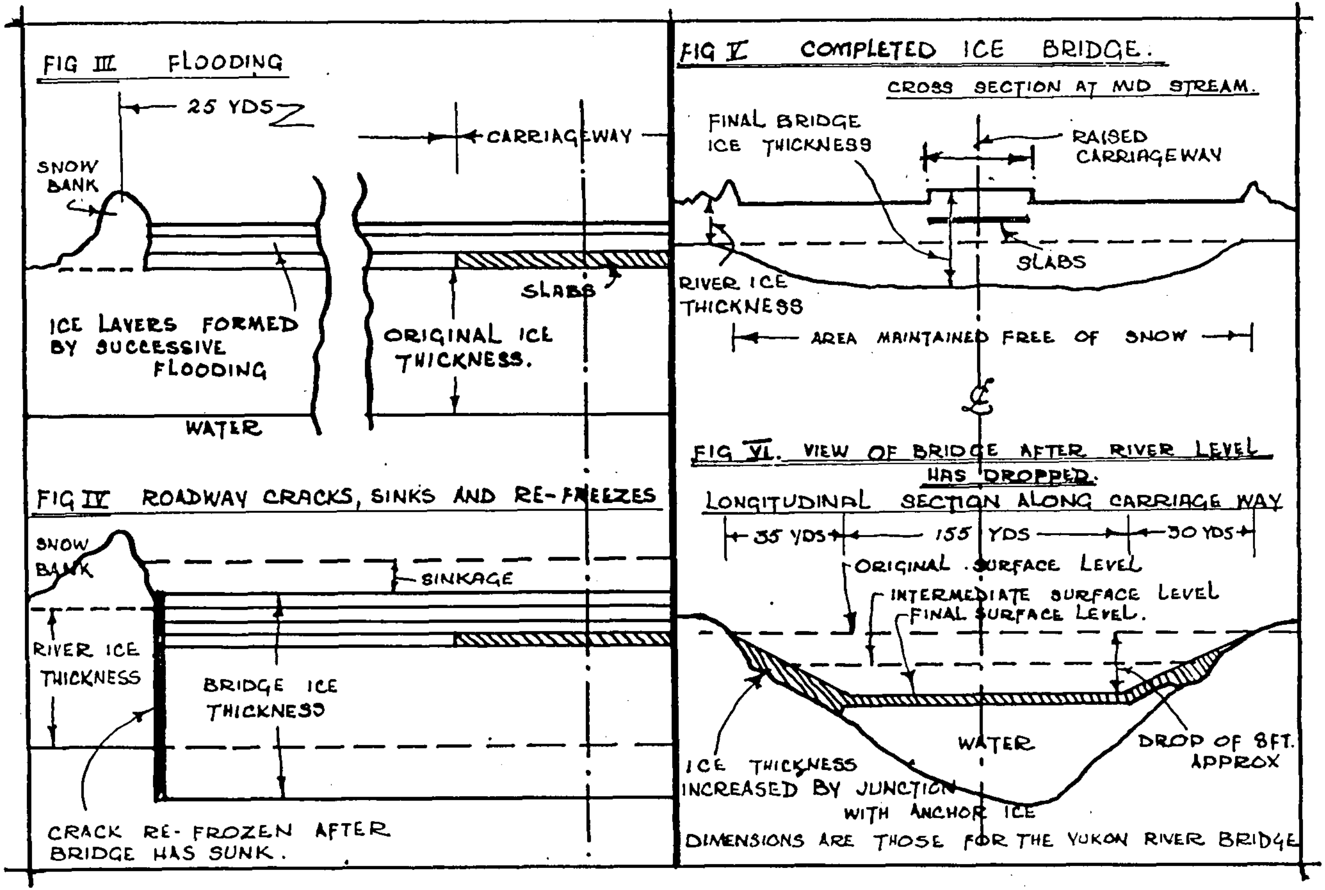


FIG III FLOODING
25 YDS
CARRIAGEWAY
SNOW BANK
SLABS
ICE LAYERS FORMED BY SUCCESSIVE FLOODING
ORIGINAL ICE THICKNESS.
WATER
FIG IV ROADWAY CRACKS, SINKS AND RE-FREEZES
SNOW BANK
SINKAGE
RIVER ICE THICKNESS
BRIDGE ICE THICKNESS
CRACK RE-FROZEN AFTER BRIDGE HAS SUNK.
FIG V COMPLETED ICE BRIDGE.
CROSS SECTION AT MID STREAM.
FINAL BRIDGE ICE THICKNESS
RAISED CARRIAGEWAY
SLABS
RIVER ICE THICKNESS
AREA MAINTAINED FREE OF SNOW
℄
FIG VI. VIEW OF BRIDGE AFTER RIVER LEVEL HAS DROPPED.
LONGITUDINAL SECTION ALONG CARRIAGE WAY
35 YDS
155 YDS
30 YDS
ORIGINAL SURFACE LEVEL
INTERMEDIATE SURFACE LEVEL
FINAL SURFACE LEVEL.
WATER
DROP OF 8FT. APPROX
ICE THICKNESS INCREASED BY JUNCTION WITH ANCHOR ICE
DIMENSIONS ARE THOSE FOR THE YUKON RIVER BRIDGE

One of the odd features of this flooding process is that, although the final flooding does cause the roadway to stand proud of the surrounding ice by six to eight inches, the majority of the increase goes to the bottom of the ice. The theory held by those making the bridge is that the flooded portion cracks and sinks along the edges of the flooded area every time a new surface, perhaps only half an inch of new ice, is added to the top. (Figs. III and IV.)

The process of flooding and build-up of the roadway is continued over a period between three or four weeks. This slow rate is due to three factors:—

(*a*) Shortage of labour.

(*b*) Low production of pumps for flooding. The one used on the Yukon has only a ⅝ h.p. engine.

(*c*) The fact that one flooding must become solid before the next layer is added. If this is not done the surface may freeze solid while water is still unfrozen underneath. The temperature at which the flooding is done will, of course, affect the flooding rate. Due to (*a*) and (*b*) above, however, and the low temperatures experienced, this factor rarely holds up work on the bridges.

Winter Maintenance

Once opened continuous maintenance is carried out on the ice bridges. Even in the coldest weather the snow must be kept cleared off the carriageway and for a short distance on either side. This is carried out because a layer of snow can act as an insulant and prevent the full freezing effect of sub-zero temperatures.

Very soon after completion of the bridge the water level in the rivers drops. This happens gradually as a rule, but necessitates ramping down the roadway at each end. Photo 2 indicates this drop, in which, at the Yukon River, the ice at midstream is about eight feet below the original level. (Fig. VI.) This lowering of the water causes a lot of work to be done on the ends of the bridge; many of the reinforcing slabs become tangled and useless. At no time during the winter is the bridge closed for change in level at the bridge site.

By the beginning of March each year the sun begins to affect the surface of the ice crossings. In order to prevent the carriageway from melting, the maintenance men cover it with sawdust. Thus after ensuring during January and February that snow does not insulate the ice against the cold, they must then protect the roadway in March against the sun by applying an insulant. The photographs attached to this report were taken after 29th March, 1954 and the sawdust covering can be plainly seen. Sawdust was found to be the best material, since a sawmill was close at hand and it is very light in weight. The colour of the sawdust is fairly light, so it does not attract heat as much as a darker substance might.

Break-up in Spring

The extra thickness caused by flooding keeps the roadway in use well into the spring. The Mayo Road is usually closed finally by deterioration of the sub-grade in the gravel surfaced road rather than by ice failure. Another reason for closure is the break-up of normal ice up and down stream of the crossing. Ice floes float down and cause pressure on the side of the ice bridge. The ice in the bridge deteriorates on the surface and bottom, but failure has not yet occurred on any of the crossings.

Full coverage of the break-up cannot be given since on this date United Keno Hill Mines operated their last ore convoy. The late break-up general in the Yukon made this a record year for closure of the Mayo Road.

Closure Dates 1953/4

These are the exact dates of closing and opening of the Mayo Road in 1953 and 1954. The formation of ice bridges in late 1953 was longer than usual due to the continued movement of ice downstream until early December.

Road closed	20th April, 1953
Ferries commenced ..	20th May, 1953
Ferries stopped	20th October, 1953
Ice bridges open ..	26th December, 1953
Road closed	6th May, 1954

Load Classification

The exact classification of the ice bridges examined cannot even be inferred, since no tests to destruction have been attempted. All crossings have, however, withstood 4½ months continuous use of fifty or more vehicles per day. United Keno use two main types of trucks, a two-axle truck and a three-axle, or semi-trailer, which carry the concentrates. The maximum gross weight of one of these semi-trailers is about twenty-five or twenty-six short tons.

The practice of flooding and reinforcing has proved itself on the Mayo Road crossings in spite of over 7,000 crossings at the same location. Whether the nominal rule as given in Army manuals and other text books (over sixteen inches, each additional inch will support the same weight in tons) can be applied is a debatable point. Taking the figure of 42 in., the minimum thickness found within 5 yds. of the Yukon carriageway, the bridge might be said to be capable of supporting 42 tons. The nominal rule should, however, be viewed with suspicion since two D4 caterpillar tractors, weighing about seven tons, went through a thickness of 12 and 13 in. of ice respectively. The condition of the ice and rate of freezing have, of course, to be taken into account.

Photo 1.—Ice bridge at Yukon River. General view looking north. Bridge length 220 yds.

Photo 2.—Southern bank showing ramped down ice approach.

Ice Bridges 1,2

Photo 3.—Ice Bridge at Yukon River. Detail of raised carriageway and sawdust covering.

Photo 4.—Ice bridge at Pelly River. General view looking north (note damp roadway) Bridge length 230 yds.

Ice Bridges 3,4

Summary on Mayo Road Ice Bridges

The bridges studied undoubtedly prove effective in carrying continuous traffic throughout their life, even during April and part of May when air temperatures are frequently above freezing. The method of construction appears to ensure an adequate thickness to prevent failure through breaking or erosion. The timber slab reinforcement is an unknown asset. It must to some extent spread the load over a considerable area and so prevent excessive shear under the axles of the heavily laden trucks. The measurements made by drilling would seem to prove that the ice forms an under-slung bulge which, in addition to the added ice thickness, causes the water to exert a greater buoyant pressure. The sawdust insulant placed on the carriageway definitely retards melting there. The surface under the sawdust was solid ice when, just at the edge, water or slush to a depth of about three inches existed on the surface at the side of the carriageway.

Military Requirements

From a study of the Mayo Road ice bridges, it is clear that the following must be done to adapt to military needs:—

(*a*) Increase the load bearing capacity.

(*b*) Increase the width greatly so that more than one carriageway can be used.

(*c*) Increase construction speed.

(*d*) Subsidiary requirements, such as lengthening the life of such a bridge, which should be achieved if (*a*) is attained.

Increase in Load Capacity

The writer will not presume to suggest a figure for ice thickness to support 80 tons. The condition of the ice, method of reinforcing, depth of water below the ice and many other factors will cause a variance in strength for such a load. If, however, care is taken in testing and construction, it is felt that an ice crossing for Centurions could be constructed by having an ice bridge of 5 ft. 6 in. in thickness. For a limited number of passes this figure might even be reduced to 5 ft. These figures are given only to provide a target, and would have to be subject to exhaustive tests and user trials. An increase in width of bridge would also give greater strength and durability.

Method of providing reinforcement would have to be further examined. The weight per foot of rolls of Sommerfeld track, for instance, may be less than that for timber slabs but not efficient enough a reinforcement to spread the load. Additional layers of reinforcing near the surface would probably be necessary for the 50-ton tank.

Increase in Width

The single carriageway on the crossings studied would not be sufficient for military use. It is advisable to widen the crossings from the strength aspect and in turn more crossing carriageways could be constructed. If the River Yukon (220 yds. across) is taken as an example, the width of the crossing might be planned as 250 yds. This would allow for five crossing lanes each 50 yds. apart. The centre lane or two lanes could be reserved for tracked vehicles while two othere are used as up and down routes for wheeled vehicles. Perhaps the centre could be a wide wheeled vehicle carriageway, and the other four used for tracks, alternately or simultaneously as required. The great width would be a barrier against wear or scour of the bottom surface as well as giving greater strength to the crossing.

The seeming extravagance of such a wide crossing is misleading, since a number of pumps could be used. Ice will only freeze at a certain rate and while one section is freezing, another can be flooded. Thus, with adequate control and planning large areas can be flooded with only a few pumps of high capacity.

Construction Speed

If the crossing is made at any time other than early winter, it is only a matter of thickening existing ice. At the beginning of freeze-up (November in the Yukon), it may be necessary to wait some time before the ice flow stops. Damming with a log boom has been tried on the Mayo Road crossings without success.

An employee of United Keno Hill Mines gave his opinion that provided sufficient pumping capacity were available, the Mayo Road bridges could be constructed in three days. The basis for this judgement is purely on the speed at which the flooded water would form ice. Layers of $\frac{1}{4}$ to $\frac{1}{2}$ in. only are the best depths for quick and solid freezing. The figure of three days is, of course, valid only for temperatures below $-15°$ F. Above $0°$ F. would probably add an extra day.

The following paragraphs will give, in skeleton, the suggested equipment and organization for a task of constructing an ice bridge across a 200 yds. wide river, the bridge itself being 250 yds. in width. The ice thickness of the river is assumed to be three feet.

One squadron of an Engineer Regiment. Ten No. 8 pumping sets. 1,000 yds. timber or Sommerfeld reinforcements.

(*a*) Labour—two troops on alternate shifts working the pumps and dyking. The third troop helping with the initial dyking and then laying the reinforcement as it is required.

(*b*) Each pumping set located in the middle of a 100 × 50 yd. rectangle, flooding four 50 × 25 yd. rectangles all dyked off from each other.

The pumping sets have four areas of 11,250 sq. ft. which must be flooded and then allowed to freeze to a depth of ¼ to ½ in. Taking 10 gallons to the cubic foot, each ¼-in. layer requires 0·21 gallons per square foot, or each area requires 2,340 gallons. Using all four pumps grouped in parallel, 4,000 gallons per hour can be put on two areas at once for 36 min. flooding. Allow 36 min. for freezing and then the area can be flooded again. Thus the rate of growth in thickness is ¼ in. in 72 min. or 5 in. per day.

Thickness and comparative load class, assuming 3 ft. initial ice thickness would be:—

After two days	46 in.	Class 30
After five days	61 in.	Class 50

Conclusions

Military adaptation of the methods used in construction of ice bridges on the Mayo Road could result in the construction of an ice crossing, taking one squadron as labour force and ten No. 8 pumping sets. The bridge would be 200 yds. in length and 250 yds. in width capable of carrying Class 30 vehicles after two days and Centurion tanks after five days. The two days is a minimum for that class of traffic, but concentration on quick freezing for the tank crossing might reduce the time to four days for the Centurion, but this could only be achieved at very low temperatures.

To qualify the preceding paragraph, it is necessary to stress the following factors:—

(*a*) Each site must be specially studied to determine the natural ice strength. This would vary according to the speed of initial freezing, whether the water was stagnant or fast flowing, subsequent temperatures, and previous snow cover. As an example, ice viewed in February might have frozen quickly in November and been covered with fairly deep snow after only a week. The strength would not be as great for the same thickness of ice as if the freeze-up had been slow and no snow had fallen until January. The military engineer has no way, in February, of knowing the initial conditions. Some form of simple field testing equipment would be a definite aid in determining strength, but the design of such equipment might be difficult.

(*b*) The construction of a military ice bridge has been briefly described. Many factors might lengthen the time for this task. Flooding in one section must not be done faster than in another. Damming the sections is a difficult task and after a day or two the snow will have been exhausted. Uneven flooding and extra dyking may delay the task a great deal.

(*c*) Pump operation and maintenance in sub-zero temperatures must be carefully planned. Heated shelter for mechanics is essential.

It is realized that the time stated is not very quick for operational needs, but the great majority of military traffic could cross over three feet of ice. The heavier vehicles would not be able to get across a river of this width in under four days, because ice cannot be formed quicker than it is able to freeze.

Consideration should be given to construction of timber pile bridges for heavy loads. Driving piles through the ice is extensively practised in North-west Highway System. For short gaps, it would probably be quicker than flooding to gain ice strength.

The time taken to make a military ice crossing is partly offset by its resistance to destruction, and the small amount of equipment required. Natural ice may carry the initial waves of troops, but a stronger, artificially reinforced bridge of the type suggested must be soon built to carry traffic for support of the forward troops. Care in reconnaissance, planning and construction will produce a strong and long-lasting crossing for nearly all loads at present in use by the Army.

PRESENTATION OF A SILVER KUKRI TO THE CORPS OF ROYAL ENGINEERS

It is regretted that the account published in the *R.E. Journal* for March, 1955, of the presentation made to the Corps on 24th November was misleading. In fact the presentation was made by officers of the Corps of Royal Engineers to mark their service with the Gurkha Royal Engineers. This presentation was not reciprocal with the presentation of a silver statuette by the Corps to the Brigade of Gurkhas, although allied to it in spirit.

THE COMMANDER CLEARS HIS MIND

An Individual View of Military Tactics

By Brigadier K. B. S. Crawford

IN the *Sunday Times* of 3rd October, 1954, Lieut.-General Sir Brian Horrocks foretold changes in our tactical doctrine and in the shape of our army. But he said that attacks must still be made on narrow fronts and in great depth, that energetic following-up action is necessary, that air reconnaissance is vital, that existing organizations should not be broken down merely for the sake of change, and that it is still the man that counts.

As changes are contemplated, it may be opportune to consider whether the present doctrine brings out the full fighting value of a military leader. The writer does not claim that there is anything particularly new or excellent in his ideas. He gives them only in an attempt to prove that a brief crystallizing of cardinal principles is possible, and that the average commander in the field does better by devoting himself whole-heartedly to a few such ideas than by spending time on the fateful appreciations and plans, which may be likened to a former Christmas game of snapdragons: unless one is impossibly quick in eating the plum one has pulled out, it burns the fingers.

I. Military history shows that commanders of troops, some even after much war experience, are apt to miss opportunities and make errors on the field of battle. The commencement of a military engagement is a time when a great many considerations invade a commander's mind and shake his nerve, just when the fortunes of his country, the fate of his men, and his own reputation, depend on his taking successful action within a limited time; and he does not know how long the time is, because that depends on the action of his opponent. Those officers who have experiences of this kind probably do not realize until too late what sudden and severe tests they are. To succeed, a commander must have his ideas sorted out, and stick to the essentials.

His chief pre-occupation should be to discover and to strike; and a young officer who aspires to command may well begin with the idea that there is a resemblance between the spirit in which war should be waged and that in which games such as football and hockey are played. This spirit, the spirit of the initiative, the desire to dazzle and emasculate the mind of the opponent, should be the foundation of his military tactics:—

History from start to finish shows that passivity of mind is the greatest single military menace; we must make at least a preliminary decision.

Willoughby (*U.S.A.*)

Whoever reads history with a mind free from prejudice cannot fail to be convinced that of all military virtues energy in the conduct of operations has always contributed the most to glory and the success of arms. Clausewitz

Energy! Energy! Speed! Aptitude for war is aptitude for movement. Napoleon

II. When military forces are within a few hours of clashing, there are factors affecting the result about which the opposing commanders can no longer do anything, such as training and the provision of arms. But there is an important factor which arises out of their decisions on the ground; and that is surprise. To concentrate their efforts on surprising the enemy is the way to victory.

Surprise is the intense form of the initiative. It is the main principle on which a commander's mind, pressed for time, and distracted by the thousand and one other considerations he has met with in the course of his training and experience, should concentrate its activity.

III. Surprise being the critical factor, the first thing is to guard against it:—

The whole art of war consists in a well-reasoned and extremely circumspect defensive, followed by a rapid and audacious attack. Napoleon

A commander ought to say to himself several times a day: If the enemy appear on my front, my right, or my left, what should I do? If he finds himself embarrassed, he is ill-posted. Ibid.

Napoleon always showed foresight in the provision he made in the rear of his army (in case of a reverse); and in that way, even in his boldest operations, he incurred less risk than might be imagined at first sight. Clausewitz

This does not usually mean that a commander is to begin by taking up a defensive position, but that he has thought of dangerous moves the enemy might make, and is ready to block them while he is himself preparing to attack. He would generally do well to send out a quarter or more of his force to cover his front and flanks; that is, to perform two duties:—

1. To give warning of, and delay, enemy attacks.

2. To drive in the enemy's covering troops, and get information.

These duties limit each other, and depend on each other. Putting the covering force under one commander saves the waste of many men where few are wanted, and quickens a change to pursuit or withdrawal. Assignment of men and arms to a protective rôle cannot be more than a partial measure. The best guard is, having uncovered the enemy's movements, to take the initiative. The defence is an accessory to the attack. In the sense of awaiting attack it is a less inexact science than the attack, but is not to be preferred on that account. It is seldom the right policy to await attack.

IV. The next thing is to see that two processes are simultaneously in motion, and to divide most of his time between them:—

(*a*) To stimulate his service of information, and to keep improving it by every available means: by setting up a system of reports from his covering troops, from patrols, the air, prisoners taken from the enemy, spies, local inhabitants, etc.; also by liaison with co-operating commanders, and by personal reconnaissance. Good information of the enemy and his intentions, and of the nature of the ground, is essential, as well as knowledge of the progress of other forces on his own side. Reports from his covering troops and from the air will probably be his main sources of information; and the former will bear more fruit if reporting centres receive occasional visits from headquarters, and are ordered to send in messages, even if negative, at limited intervals. This must be an active, dynamic process. Some of the most important facts about the enemy and his mentality will often be discovered only by the aggressive action of covering troops.

(*b*) At the same time, to decide which part of his force is to carry out "a rapid and audacious attack", making it as strong as he can by economy elsewhere; to appoint a leader for this striking force; and to keep rearranging it and moving it about in response to the stream of information coming in, so as to try and ensure that it will be in the right place and the right order to strike at once when an opportunity comes. Less caution allows more punch, and an experienced commander will know how far protection can be cut down and his striking force increased, if he finds his opponent passive.

The whole art of war consists in getting at what is on the other side of the hill.
attributed to Wellington

Experience has proved in Malaya that Intelligence is the key to control of militant Communism. Under General Templer, security forces operated against Communist terrorists for the first time on a basis of accurate information. Other important factors contributed to the improvement under the Templer regime, but it was the High Commissioner's emphasis on Intelligence that paid the highest dividends.
Daily Telegraph

The kind of opportunity the commander is looking for is a gap, or weak sector, in the enemy's line, an exposed flank, a badly supported detachment, a key position, etc. Any considerable dent or bump in the forward line may offer a chance to attack. Like David, he has put his stone in a sling, and is swinging it about in anticipatory fashion. Having his striking force frequently on the move will give him opportunities to mystify and mislead his opponent, and to attack suddenly. To make a good feint is a form of surprise.[1] The men must have some rest, but quickest to move are those who make short stays, and slowest those who have been long in one place. A saying on strategy

[1]Cf. General Townshend's manœuvre in Iraq on 27th/28th September, 1915.

is a reminder that physical endurance is an indispensable part of military success:—

The secret of war is to march twelve leagues, fight a battle, and march twelve more in pursuit. *Napoleon*

Napoleon did not spare his armies; but they loved him.

Covering troops, too, should not get stuck down on a line; it saps their initiative, and tempts the enemy to make rings round them. This is the besetting error of hurriedly trained units. Their rôle is either surprise or ambush; or at least movement. This movement, and the loss of his men, capture the enemy's mind and help to tear away his screen.

Even if he is outnumbered, surprise will give the commander a numerical advantage at the point he chooses. It is his duty to launch an attack in good order, and to do it before the enemy attacks, as at hockey. In fact the competition for the initiative between opposing commanders resembles very much the struggle between two sides at hockey. Normally, in the tactical sphere, getting in first with a sudden well-ordered attack is the practical meaning of surprise.

The two occupations of urging on his intelligence and poising his striking force should take up most of a commander's time when battle is imminent. He must have the eye of a hawk and also its ability to drop suddenly on its prey. But he cannot expect that his picture of the situation will ever be really clear; and in order to forestall the enemy he will have to attack with just enough information and no more. "In war, time is the greatest of all risks."

This is where some commanders fail. Afraid of a little uncertainty, they ignore the danger of delay: they wait for more details—and it is the opponent who strikes first. It is the opponent who finds a weak spot and there suddenly applies three or four men to one. Chesterfield's words on a non-military subject describe well the action of bold commanders:—

They see the weak and unguarded part, and apply to it; they take it, and all the rest follows.

All the rest follows—provided they don't stop to eat, or lie down.

It is not the number of unassailable positions in all directions, not the formidable dark mountain masses around the theatre of war, or the broad river which passes through it, not the ease with which certain combinations can effectually paralyse the muscle which should strike the blow against us—none of these things are the true causes of the success which the defensive gains on bloodless fields; the cause lies in the weakness of the will with which the assailant puts forward his hesitating feet. *Clausewitz*

The cause of the (German) débacle in Tunisia was fundamentally the same; it was the cumulative effect of the succession of hammer-blows delivered by our armies from Alamein onwards. Sheer hard fighting did it. It was the apotheosis of the offensive. The lesson is clear—there is no short cut to victory—sheer

hard fighting, such as our troops employed on Long Stop Hill of glorious memory, in an implacable offensive, is the only sure precursor to victory in war.
Burne

Such a succession of blows can best be struck by a team of military leaders, united by their regard for one another or by the commanding presence of their chief, advancing together, like a cup-winning hockey team with their eyes wide open and their sticks in the readiest position in their hands.

To gain full advantage of the immense fire-power that nuclear weapons have provided, and to avoid destruction by enemy nuclear attack, armies must develop a more lively and opportunist type of battle leader than exists at present, in both junior AND senior ranks. Such a leader must have the imagination, the daring, and the resources to seize fleeting local opportunities; he must be trained to act independently and immediately within the framework of a general plan, rather than on precise and detailed orders or only after reference to a superior.
F. M. Visc. Montgomery, Lecture at the R.U.S. Institution, 21st October, 1954

A bold general may be lucky, but no general can be lucky unless he is bold.
Wavell

Tactical ability is ability, not merely to make use of ground and other early-known factors, but to beat an enemy who makes unforeseen tactical moves:—

He had already deduced from his military experience the conclusion that in war the most deeply considered plans have no significance, and that all depends on the way unexpected movements of the enemy—movements that could not be foreseen—are met; that all depends on how, and by whom, the whole matter is handled . . . What one had to do was not to reason, or stick pins into maps—but to fight, beat the enemy, keep him out of Russia, and keep up the spirit of our army. *Tolstoy*

One can agree that all depends on getting the right man to handle the matter; but what of the others, not so well endowed with the hawk's eye and the hawk's swiftness in striking?

They need a streamlined method, related to familiar ideas:—

This order of battle will reduce the form or manner in which the army fights to a kind of method, which is very necessary as well as salutary, because a great number of the generals of second order, and other officers at the heads of smaller formations, have little knowledge of tactics, and no special aptitude at all for war. By this, a certain methodicism is instituted which takes the place of art, where the latter is wanting. *Clausewitz*

The German tactical method was reputed to be too detailed and inflexible. The British method on the other hand has been dependent, in the writer's view, on the rapid application in the stress of action of too many general principles.

V. A commander will keep a part of his force in reserve, and handle it in much the same way that he handled his striking force:—

The solution seems to be that the reserve should be freely and boldly used, but that directly that has been done instant steps should be taken to build up a fresh one. It was in this respect that Sir Douglas Haig excelled in the Battle of Ypres. He was constantly launching his tiny reserve into the battle, and as often scraping together another from byways and hedges. *Burne*

VI. At intervals a commander needs to give attention to two other things. One is administration. Here he will not have to do all the thinking; but he must direct. Sometimes administration becomes a chief concern.

The other point is to keep up the morale of his troops. He must find ways to inspire them. He himself should look confident and cheerful, remembering that it was probably Monmouth's tragic face that lost him the Battle of Sedgmoor:—

I declare when I have seen him riding among his troops with his head bowed upon his breast and a face like a mute at a burying, casting an air of gloom and despair all round him, I felt that, even in case of success, such a man could never wear the crown of the Tudors, but that some stronger hand would wrest it from him. *Conan Doyle*

If the leader has his mind on the essentials of his task he will be confident, and confidence is catching. The supreme stimulant is to surprise the enemy; by depressing the other side it has a double effect.

Commanders are strong when they direct not merely the movements and actions of the soldiers, but can direct their spirit. *Tolstoy*

VII. In short, a commander in battle is mainly concerned with getting information and launching attacks. He is also concerned with administration and morale. He should apportion his time to these four matters in accordance with their importance, and do his best to keep all other thoughts out of his head.

Whether he is a corporal or a colonel, the commander's career will sometimes have been built more upon the staunchness of his heart than the wiles of his mind. This is right and inevitable:—

Those steadfast natures which can better be depended upon, which in a battle are impregnable to fear and immovable, are equally immovable when there is anything to be learned; they are always in a torpid state, and are apt to yawn and go to sleep over any intellectual toil. *Plato*

A man faced at every stage by a tedious mental process, with the risk of forgetting some principle on the one hand, and the danger of delay on the other, cannot be revelling in the exercise of his abilities. In this difficulty some are happy to avoid disaster; a few seize half consciously upon almost any diversion. The writer can remember two commanders whose thoughts were drawn away from the right channels at critical times. He was once galloper to a brigade-commander who, in the middle of an engagement, with bullets flying around and shell bursting, turned back to look for a gold ring that he thought he had dropped in the mud. The enemy were driven back on that occasion, but there was no finesse; it was a Soldiers' Battle. Another commander in action was in discordant relations with a brother commander, which took up most of the thoughts of both of them.

VIII. The special virtues of a soldier are courage, obedience, and vigilance. The first is the master quality. Often one commander imposes his will on the other almost throughout. But sometimes no weak place is found, the battle is long drawn out, and the issue remains in doubt until the end. In such struggles a commander can only get the best out of himself and his command by exercising inflexible resolution:—

It is by his courage—by his courage alone—that a gentleman can make his way nowadays. Whoever hesitates for a second perhaps allows the bait to escape which during that exact second fortune held out to him. — *Dumas*

It is now time when the outcome of the struggle is to be decided. We cannot afford to rely on other countries any more; rather we must save ourselves with our own strength. This crisis of ours must never be made known to Germany. For this purpose it does not matter if the British forces are annihilated. We must attack Germany vigorously. — *Lloyd George*

When we encounter severe enemy attacks we should rejoice in the anticipation of dealing a crushing blow. When the situation becomes more tense and our comrades fall in succession, then we must be glad to have the opportunity of annihilating the enemy. The severer the battle becomes, the greater is the possibility of crushing the enemy. It is then that we must whip up our resolve and concentrate our total energies.
Col. Yasumasa Ishida, Instructor, Japanese Staff College

IX. In a pursuit it is necessary to drive the enemy hard from behind, as well as cutting him off. Otherwise he may re-form, recover his morale, and a second battle may have to be fought, against a rat in a trap.

The most decisive losses on the side of the vanquished only commence with the retreat. — *Clausewitz*

X. If a commander has to withdraw his force in face of a much superior enemy, he must still attack. In this case he will try to destroy parts of the hostile army before their main body can save them.

To watch and to attack is the only hope.

"Attaquez! Attaquez! Attaquez! Tout le monde à la guerre!" — *Foch*

THE IMPORTANCE OF THE CHINESE RAILWAY SYSTEM WITH REGARD TO THE SITUATION IN THE FAR EAST

By MAJOR I. HARDIE, R.E.

THE object of this paper is to consider the significance of the part played by the Chinese railway system in the events which have occurred in the Far East and South-East Asia between 1949, when Mao-tse-tung established himself as ruler of China, and the signing of the agreement on Indo-China in Geneva this year.

The most important event during this period is undoubtedly the rise of China to the status of a world power.

Since China is not yet a maritime power, the Chinese railway system has peculiar significance with regard to the situation in the Far East and South-East Asia and much may be learned from a close examination of this aspect of the country's economy. It is by far the most important transport agency in China and the economic expansion and strategic aims of that country must be largely dependent upon it.

Geographically, the system can be divided into three parts (see map on folding plate facing page 188):—

(*a*) *Manchuria.* This is the most modern and efficient part of the whole network. It is also the most dense part and has alternative routes between most of the important places. It serves the Manchurian industrial complex and interconnects Russia, North Korea and China proper. The backbone of the Manchurian railway is formed by those lines formerly known as the Changchun Railway. They are the line which connects Manchouli, via Harbin, with Suifenho and the line from Harbin to Dairen and Port Arthur[1]. Manchouli and Suifenho are the only points at which the Chinese and Russian railway systems meet and hence the line connecting these two points is of great strategic and economic importance to China. It is also important to Russia since it forms a short alternative to the Trans-Siberian Railway though it must be remembered that the Chinese gauge differs from the Russian and it is, therefore, necessary to trans-load at the border.

There are several rail connexions between Manchuria and North Korea but only one between Manchuria and China proper. This latter line follows a strategically vulnerable route along the Gulf of Chihli and is the only rail link between China proper and the Manchurian and Russian industrial complexes. Its strategic and economic importance is therefore obvious.

[1]Until the end of 1952 the Changchun Railway was under joint Sino-Soviet control. On 31st December, 1952, it came under full Chinese control and was renamed the Harbin Railway Administration.

(*b*) *China North of the Yangtze.* A very sparse network consisting of two north–south trunk routes, with only three lateral connexions. There is also an important but isolated line connecting Chunking with Chengtu.

This part of the Chinese railway system serves the new area of industrial expansion in West and North-West China and contains most of the important railway projects. The two north-south trunk routes are the main lines of communication for movement from industrial Manchuria and Russia towards South East Asia and Hong Kong.

The lack of alternative routes makes this part of the system particularly vulnerable, but it is nevertheless of great strategic and economic importance.

(*c*) *China South of the Yangtze.* An even sparser network than that north of the Yangtze. It contains four main lines which form a letter "K". The two northern points are at Wuchang and Nanking from both of which lines run to Chuchow. From Chuchow there is a rail bottleneck south to Hengyang, from which point one line runs to Pinghsiang, near the Indo-China border, and another to Canton.

There is also an isolated metre gauge line serving Kunming and the mining area to the south-east.

The strategic importance of the network south of the Yangtze has been greatly increased by the move of the military centre of gravity from Korea to South-East Asia. At present movement between north and south China, including the re-deployment of locomotives and rolling stock, is hampered by the fact that there are no rail bridges over the Yangtze and everything must be ferried at Nanking or Hankow.

By the end of the Sino-Japanese and subsequent civil war a large part of the railway system of China proper was out of action. The Manchurian system did not suffer so badly, but the industrial rape of Manchuria carried out by Russia immediately after the war must have seriously affected the productive capacity of the railway industry. This may since, to some extent, have been made good, but it is likely that there is still a shortage of locomotives and rolling stock.

In 1949 the Communist régime realized the important part that the railways would play in the rehabilitation of the country and subsequent economic expansion and devoted every effort to the rapid restoration of the system. Technical help and perhaps a little material help were supplied by the Russians and some U.N.R.R.A. stores may have come into Chinese Communist possession, but there must, nevertheless, have been a severe shortage of locomotives, rolling stock, rails, bridging steel, signal and telegraph equipment and almost everything other than unskilled labour. Therefore it can be deduced from the speed with which several thousand miles of line were brought back into operation that many temporary improvisations were incorporated in the work. It was no doubt intended to improve and consolidate the lines as and when technicians and materials became available, but they could not have been operating as efficiently, nor could their capacity have been as great, as it was under the Japanese.

As soon as the temporary restoration of the major part of the old system was completed the Chinese Ministry of Railways embarked upon a programme of capital constructions. The new lines, as well as being strategically important, are a necessary part of the general programme of economic expansion. The pattern of new construction is now becoming clear: the only main line serving the extreme south has been extended from Nanning to the Indo-Chinese border; part of a new north-west south-west trunk route to connect Paotou in the north with Kumming in the south is under construction and the remainder is scheduled for construction in the near future; the most important lateral line, the Lunghai Railway, has been extended from Tienshui to Lanchow and a new line is being constructed west from Lanchow across Kansu and Sinkiang to connect up with the Russian Turk-Sib Railway; a railway and road bridge is under construction across the Yangtze between Hankow and Wuchang. These are the major projects at present in hand and their strategic significance is that they improve communications with South-East Asia on the one hand and Russia on the other. In particular the Sinkiang line will form an alternative to the strategically vulnerable Gulf of Chihli line. The Yangtze bridge will speed up any north–south re-deployment of troops, stores, locomotives and rolling stock that may become necessary in the future. Their economic significance is that they will facilitate the development of oilfields and mineral deposits in Kansu and Sinkiang, and will enable new industrial centres to be established in strategically safer areas in the west of China. Their political significance is that improved communications will facilitate effective political control of the minority peoples of the extreme west by the Chinese Communist Government. Also, since a basic shortage of technicians, aggravated by purges to consolidate Communism and eliminate corruption, necessitates acceptance of Russian help, it follows that there is Russian influence on the planning level.

The rapidly increasing volume of traffic resulting from industrial expansion, new railway construction and the need to maintain and improve the original hasty rehabilitation of the railway system, coupled with a shortage of locomotives and rolling stock and inefficiency due to lack of experienced personnel must have severely strained the Chinese railways. It is, therefore, probable that the unexpected but prolonged additional load resulting from the Korean War caused the strain upon the railways to become critical.

The many "emulation" campaigns entailing the over-loading of rolling stock and over-working of locomotives are evidence of the difficulties under which the Chinese railways were operating prior to the summer of 1953.

It is unlikely that China could have continued to support the Korean War without severely curtailing her own programme of economic expansion and the Korean armistice was therefore a necessity. Having ended the fighting in Korea, the logical next step, from the Chinese point of view, was quickly to gain as much success in Indo-China as could be achieved without incurring full scale military intervention by the United Nations. Large-scale intervention by the United Nations, with naval and air superiority, would have been much harder to contain in Indo-China than Korea. There is only one railway line to support Chinese intervention in Indo-China, whereas North Korea has five rail links with Manchuria and has direct access to Russia across the Tumen river. In any case, if China could not continue the war in Korea, she would not wish to replace it by an equally heavy military commitment in Indo-China.

It therefore seems likely that Northern Vietnam might have been saved had the status of Indo-China been included, with French consent, in the terms of the Korean armistice.

From the purely military point of view, United Nations' intervention prior to the Korean armistice would have forced China to abandon Indo-China or fight on two fronts. In the latter event it is difficult to see how China could have avoided military defeat in one or both of the theatres, unless Russia had intervened in Korea and enabled her to concentrate against Indo-China. Direct Russian intervention in Korea would presumably have resulted in the expulsion of Russia from the United Nations and it is doubtful whether China could have re-deployed sufficient force from the extreme north to the extreme south (bearing in mind that there is only one rail approach to Indo-China south of Nanning and no bridges over the Yangtze east of Hankow) in time to prevent a major United Nations' victory in Indo-China. Chinese action against Indo-China once United Nations' forces had reached the Sino-Indo-Chinese border might have resulted in the bombing of Chinese communications and industrial centres. This might have touched off a third World War.

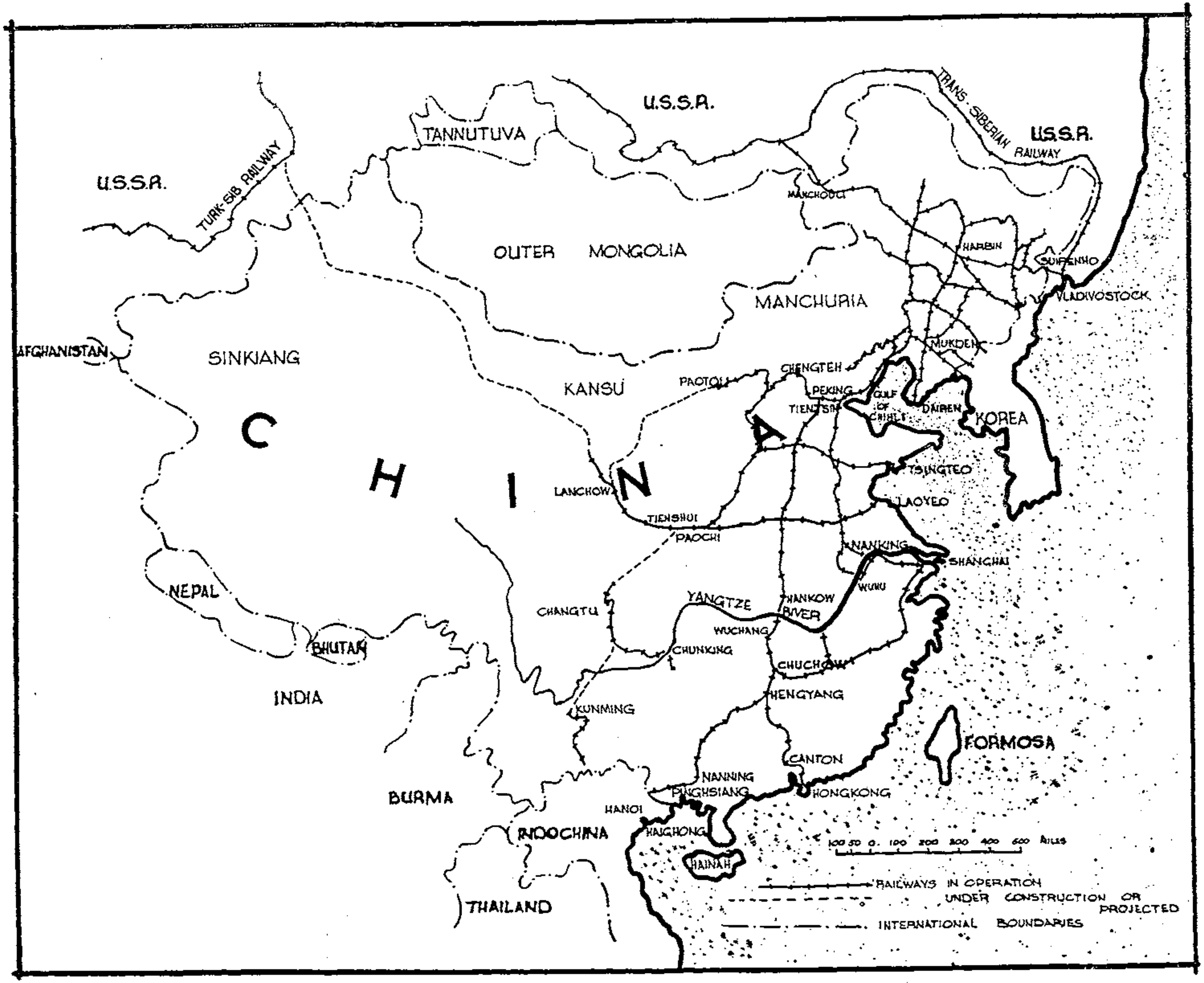
It therefore appears that United Nations' intervention in Indo-China prior to the Korean Armistice would have faced the Sino-Russian axis with three alternatives: to abandon Indo-China, to start immediate peace negotiations or to widen the scope of hostilities and risk a third World War.

The advance of Communism since the second World War has shown that the placing of the Communist powers in a position similar to the one outlined in the preceding paragraphs is a calculated risk which must be taken sooner or later if the spread of Communism is to be checked. The later it is taken the greater the risk will become.

At the present time it is unlikely that the Communist powers could win a third World War. Therefore they are unlikely to risk starting one and it follows that United Nations' intervention in Indo-China prior to the Korean Armistice would probably have resulted in an immediate Chinese offer of peace negotiations. Such an offer would undoubtedly have been surrounded and obscured by much anti-West propaganda, but the United Nations would have been in a strong position from which to negotiate conditions favourable to the free world. In the actual event, the Communists have gained control of Northern Vietnam, the Southern Vietnam Government is discredited in the eyes of its supporters and is without authority, the Southern Vietnam Army is no longer an efficient and reliable fighting force and the whole of Vietnam is likely to come under Communist control sooner or later.

For the future, it is difficult to suggest how the initiative can be wrested from the Communists if we are to continue fighting them only at times and in places of their choosing. From the military point of view, further serious Communist aggression in South-East Asia might be countered by unleashing the South Koreans against North Korea with the United Nations in reserve. However, during the next few years China may be largely occupied in expanding her industries and improving and extending her internal communications.

The above analysis of the situation in the Far East has ignored many factors which affect the situation. Public opinion in America, Europe and the free countries of South-East Asia; the extent of military resources available to the United Nations; the economic implications of intervention in Indo-China and many others, but with due allowance for these shortcomings, it is still difficult to avoid reaching the conclusion that, in the Far East, the "West" has received a sharp lesson in the art of political and military strategy. Let us hope that we have learnt our lesson well.


U.S.S.R.
TURK-SIB RAILWAY
TANNUTUVA
U.S.S.R.
TRANS-SIBERIAN RAILWAY
U.S.S.R.
MANCHOULI
OUTER MONGOLIA
HARBIN
SUIFENHO
VLADIVOSTOCK
MANCHURIA
MUKDEN
AFGHANISTAN
SINKIANG
KANSU
PAOTOU
CHENGTEH
PEKING
TIENTSIN
GULF OF CHIHLI
DAIREN
KOREA
CHINA
TSINGTEO
LANCHOW
LAOYEO
TIENSHUI
PAOCHI
NANKING
SHANGHAI
WUHU
NEPAL
CHANGTU
YANGTZE RIVER
HANKOW
WUCHANG
BHUTAN
CHUNKING
CHUCHOW
INDIA
HENGYANG
KUNMING
FORMOSA
CANTON
NANNING
BURMA
PINGHSIANG
HONGKONG
HANOI
INDOCHINA
HAIPHONG
HAINAN
100 50 0 100 200 300 400 600 MILES
RAILWAYS IN OPERATION
UNDER CONSTRUCTION OR PROJECTED
INTERNATIONAL BOUNDARIES
THAILAND

WATER HEATING FOR DOMESTIC PURPOSES IN THE TROPICS

By MAJOR E. W. CHRISTMAS, R.E.

ANYONE who is, or has been resident in the tropics, will no doubt be familiar with the possibility that the cold water tap may supply quite hot water for a period when first turned on. This effect is of course due to the practice prevalent in such parts of the world, of running pipes on the outside walls of buildings (there being no freezing problems to consider) and consequently they are heated by the sun's rays.

The following is an account of some experiments carried out in Jamaica, and in case the reader is not familiar with the Jamaican climate, it might be as well to mention that day temperatures are generally between 80 and 90° F.

It was discovered that the temperature of the water could be as high as 110° F., instead of the normal 75 to 80° F., and it was decided to endeavour to devise some cheap and simple way of utilizing this effect to provide hot water in larger quantities for domestic purposes.

From observations of a small cold-water reserve tank erected in the open, it was apparent that the bulk of the water remained at normal temperature, obviously due to the small area of heating surface compared with the quantity of water. A small metal cylindrical vessel of about one pint capacity and filled with water was therefore placed in the sun, and the following results obtained:—

Time	0900	1100	1200	1300	1400	1600	1900
Temp. ° F.	80	100	111	122	125	122	80

The day was practically cloudless, and sunset at 1730 hrs.

This little experiment was carried out as a preliminary to further investigations based on the following:—

(*a*) That in order to obtain useful temperatures, a large heating surface area in proportion to the quantity of water is needed.

(*b*) That unless the water is mixed by stirring, or otherwise moved, only a top layer is heated.

(*c*) That the temperature of the water rapidly returned to air temperature as soon as the sun's rays were removed when the requirements of (*a*) above were met.

(*d*) A shallow sealed container is obviously needed, so that the water would be in direct contact with a large surface heated by the sun, for as long a period as possible.

(*e*) Since it is impracticable to stir the water, arrangements are needed to enable the effects of convection to be utilized.

To serve as a heater, and take the place of the usual boiler, a sealed sheet metal container, 1 ft. square and 2 in. deep, was made. This was fitted with a flow pipe on top, and return pipe below and connected, by means of rubber and glass tubes for convenience, to a 1-gallon cylinder placed in wood sawdust as lagging.

With this "heater" placed flat on the ground in the sun, 1 gallon of water was heated from 80° F. at 0900 hrs. to 135° F. at 1300 hrs. and thereafter the temperature remained constant. From this it was deduced that such an arrangement on a larger scale would produce desired results, since water at 135° F. is ample for normal domestic purposes.

From the above it will be seen that 1 sq. ft. of heating surface produced 1 gallon of water heated through 55° F., or 550 B.T.Us., in four hours with continuous sunshine.

It was therefore decided to use this method to supply the requirements of five adults for slipper baths only, estimated at 50 gallons of hot water at this temperature per day, when mixed with cold water at 80° F.

For this purpose a flat-bottom heater tank, 8 × 7 ft., sloping at the top from 1 in. deep at the two sides to 3 in. deep at the centre, was made, the top being sloped to induce natural circulation towards the flow pipe fitted centrally. This was installed on the flat roof of the existing boiler house, and supplied a 50 gallons capacity lagged storage cylinder.

Since it is obviously impracticable to anticipate continuous sunshine daily throughout the year, a 1½ kW. thermostatically controlled, electrically heated, immersion element was installed in the storage cylinder. The element was switched on from 1400 to 1800 hrs. daily, and the thermostat was set at 130° F. so that it would switch in only if there had been insufficient sunshine.

In order to check results as far as possible electricity and water meters were installed to record consumption, and it will be seen from the following that the results achieved over a six month period have been remarkably near those anticipated:—

Actual gallons hot water consumed 7,200 gallons	40 gallons daily
Electricity consumed	600 units
B.T.Us. supplied to heat water 80 to 130° F. ..	3,600,000
Equivalent electrical energy	1,040 units
Actual equivalent energy derived from sun heating	440 units

This represents a saving of well over 40 per cent in electric energy consumed, since the figure of 80° ambient is the maximum.

These figures are obviously not fully accurate, as the record does not prove that water was always drawn off at 130° F. Since, however, an average of 40 gallons daily has been used, it is reasonable to assume that five hot baths were provided daily, and that the water was not used except when heated.

This installation was more in the nature of an inexpensive experiment, and served to prove the economic practicability of such an arrangement. No doubt much better results could be obtained with more elaborate arrangements at a consequently greater cost.

Major-General EHW Cobb CB CBE

MEMOIR

MAJOR-GENERAL E. H. W. COBB, C.B., C.B.E.

EDWYN HARLAND WOLSTENHOLME COBB, the second son of Mr. W. H. Cobb, I.C.S., of Oak House, Baughurst, Hants, was born at Naini Tal on 6th August, 1902.

From early childhood he showed a remarkable capacity for observation, a strong memory and a fearless disposition. Active and enterprising, his lifelong interest in riding and golf started while he was still a youngster in India.

At the age of seven, he went to Summerfields, where he later became head of the school and distinguished himself at cricket, football, golf and diving before passing as First Scholar into Winchester. His early promise qualified him there for the post of "Writer" to J. d'E. E. Firth, then Prefect of Hall, and while still a junior his diving prowess won him the school "purling" off "Senior-Senior". At Winchester, his interest in photography and carpentry developed, and he became increasingly attracted to mathematics and science. To the great disappointment of the Headmaster, he decided to follow the earlier example of Lord Wavell and adopt the Army as a career. He passed well into the Shop where he was runner-up for the Saddle and was commissioned into the Royal Engineers on 31st January, 1923, at the head of his batch.

After some months at Chatham and Aldershot, during which time he won the Army Diving Competition, he sailed in 1925 for India, where he was to spend the next twelve years. Starting in the K.G.Vs. O. Bengal S. & M. at Roorkee, he was posted later as Assistant Garrison Engineer first at Nowshera and then at Landi Kotal. After nine months on works he returned to Roorkee to spend the next four years in such varied appointments as Assistant S. of I., Assistant Adjutant, Q.M. and Company Officer.

In 1930 he obtained the much coveted command of the Chitral section and spent the next two years building roads and bridges, shooting, ski-ing and playing polo. His elder brother had previously been in Chitral in a political capacity and Eddy followed in his steps by accompanying the political agent on an Indo-Afghan boundary commission. After a long leave at home, he became Corps Adjutant at Roorkee, where he remained for three years, becoming a first-class polo player and spending his leaves shooting in the Himalayas, in the course of which he was fortunate enough to bag two tigers. In spite of these activities, he passed into the Staff College and spent a happy two years (1937–9) at Camberley, hunting with the drag, playing hockey and golf for the college and earning an excellent report for his work.

During this time he married Miss Priscilla Landon, and in 1939 they returned together to India where he spent a year on the staff at Army H.Q. before being promoted to Major and being recalled to Camberley in 1940 as an instructor. After two first-grade staff appointments in York and at the War Office, he was posted in June, 1942, as C.R.E. 52 (Lowland) Division, which was being specially trained for mountain warfare. It was always a regret to him that he was not destined to take his divisional sappers into action but, after only a year in command, he was promoted to Brigadier and transferred back to India to become D.D.M.O. (Plans) at G.H.Q. and, a few months later, B.G.S. (Plans) at 11 Army Group. He was awarded the C.B.E. in 1945.

December, 1944, gave him his first taste of active service, beginning as B.G.S. 4 Corps and later taking command of 33 Infantry Brigade. He went to the I.D.C. in 1947, but left before the end of his course to go as a Major-General with the U.K. delegation to Burma.

In 1948 he became D.D.S.D. at the War Office and in 1950 he went back to Camberley for two years as Assistant Commandant (and, for part of the time, as Acting Commandant) of the Staff College. Eddy Cobb had always had a sympathetic interest in people and the close association with so many officers from all over the Commonwealth made this a full and enthralling appointment. He left it with great regret in 1952 to become Director of Manpower Planning at the War Office, one of the most exacting Major-General's posts in the Army. He was ideally suited to the job, combining an analytical brain with inexhaustible determination and energy. It is difficult to overestimate what the Army owes to his unflagging activities during the two years he held the appointment, and many of us will remember with great affection the bowler hatted figure of Eddy, riding his "Corgi" down Whitehall to some inter-departmental conference, at which he would fight most vigorously on behalf of his service.

Amongst his achievements as D.M.P. was the opening of Welbeck College, to train officer material from the industrial areas for the technical branches of the Army.

His great services were rewarded by a C.B. in January, 1954, and, in the same year, he became Commandant of the Royal Military College of Science at Shrivenham.

In the few months he remained at Shrivenham, before his tragic death on 26th March, 1955, he had begun to impress his strong personality on the College and to unite in a growing comradeship the military and civil personnel of the staff and students.

His loss is being deeply felt throughout the Army, where his sterling Christian qualities, his humour, his broad humanity and his never-failing sportsmanship endeared him to his brother officers and men of all ranks. Our deepest sympathies go out to his wife and small daughter who survive him.

A.D.C.

BOOK REVIEWS

ROME, BEYOND THE IMPERIAL FRONTIERS

By Sir Mortimer Wheeler

(Published by Messrs. G. Bell & Sons, Ltd., 1954. Price 25s.)

Many of the lands, which Sir Mortimer Wheeler describes so effectively in *Rome, Beyond the Imperial Frontiers* have been, or are now, garrisoned by British troops—a significant reminder that soldiers should not think that archaeology is off their beat.

Sir Mortimer deals first with Free Germany, which is the name he gives to the country east of the Rhine and north of the Danube, which never came under Roman rule. We learn that the Roman passion for amber ornaments had much to do with the establishment of trade routes from the Mediterranean to the Baltic. The trade to the north took with it specimens of every kind of Roman handwork, from humble bronze pails to finely wrought silverware and gold coins. In due course, such objects went into graves and hoards, from which, after the lapse of many centuries, they are being steadily extracted by diligent archaeologists and tied up to history. Particularly interesting is the fact that most of the gold coins of Augustus found in Free Germany came from the vicinity of the Teutoberger Wald, near Bielefeld, where in A.D. 9, Varus lost his legions and his life.

Although Free Germany is more fully treated than either Africa or Asia, readers will perhaps agree that the most interesting part of the book deals with India, whose fabled eastern splendours have had such an enduring attraction for the successive civilizations of the West. Those familiar with the Buddhist cities of Gandhara near Peshawar and of Taxila near Jhelum will be pained to find that the credit for the famous classical ornamentation of those places is removed from Greece and given to Rome. But Sir Mortimer has good reasons for believing that the surviving Hellenism of Bactra had practically vanished long before Gandhara and Taxila took shape. Thus the new Buddhist art, which developed with the deification of Buddha some time in the first century B.C., had to draw on Roman craftsmen for its classical forms. The question is largely one of dates. When Sir Aurel Stein was excavating in Gandhara nearly fifty years ago, he was never very precise about its date and spoke more of the influence of Greece than that of Rome. Archaeology clearly moves on, just like any other science.

The sketch maps, drawings and photographs of works of art are admirable, whilst the well planned letterpress contains an impressive wealth of detailed learning. *Rome, Beyond the Imperial Frontiers* is a fascinating example of archaeological reconstruction. It gives a wonderful picture of the great city reaching far out to distant lands, not for wearisome raw materials, but for luxuries with which to add to the splendour of her existence. B.T.W.

THE DECISIVE BATTLES OF THE WESTERN WORLD, Vol. II

By Major-General J. F. C. Fuller, C.B., C.B.E., D.S.O.

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

Volume II of General Fuller's impressive history of war fully maintains the high standard of its predecessor. The narrative has got nearer to our own times: the interest is enhanced. The reader has now got his second wind and is moving through country with which he is more familiar.

Although no longer gasping for breath, he will still be staggered by the wealth of knowledge and industry which the General has brought to his task.

Examination of the sources of his well marshalled facts show clearly that he has undertaken a great deal of new research. It also reveals him to be most punctilious in the acknowledgement of quotations. Your reviewer noticed with interest that other distinguished workers in the same field are occasionally not so particular. The temptation to transplant a lively paragraph, unacknowledged, is sometimes irresistible. The author's intervening chronicles are here and there so crowded with information that the going gets a bit laboured. New material adds enormously to the interest of the battles. This is particularly so in the account of Waterloo where the onset of the Prussians is woven most skilfully into the story of Wellington's great battle.

The author does not yet come to any main conclusions about the cumulative effect of war on history. But on the dust cover of the book reference is made, surely by General Fuller himself, to Kant's *Zum Ewigen Frieden.* In this treatise Kant suggests that wars tend, in the long run, to unite the human race. The goal of Providence is concord: her driving force is discord. This is comforting thought.

The end of this volume sees the triumph of what Napoleon called the English System. Great Britain is enabled thereby to establish a measure of concord throughout the world for over a century. Discord, however, still has more work to do. Volume III will show what it is. B.T.W.

HOW TO LIVE WELL ON YOUR PENSION

By W. P. A. Robinson

(Published by Faber & Faber, Ltd. Price 12s. 6d.)

The author is a keen practical gardener and has previously published a book entitled *How to Make Your Garden Pay.* It is natural, therefore, that more than half the present book is devoted to gardening. The points he stresses are how to run quite a small garden with the minimum of labour and make an addition to one's pension by selling the produce to local shops and in other small ways. There is much sound advice as to what to grow and what not to grow, as well as how to grow it. He stresses the point that the only way to make money out of this is to produce your flowers and vegetables early when you can get a good price for them.

Throughout this part of the book he stresses the fact that one must remember that after retirement one is not as young as one was and, therefore, one must reduce labour to a minimum so that work is a pleasure and not a toil. He considers a rotary cultivator is an essential in spite of its price.

There is a chapter on pests and how to deal with them. After reading this chapter one wonders if it is possible to grow anything, but he points out that the pests don't all come all the time.

There is a chapter on poultry keeping, in which he recommends keeping hens for laying rather than breeding chickens and selling them or raising cockerels for table birds. He gives brief details of batteries, free ranging and deep litter methods.

I have left comment on the first part of the book to the end. In this he deals with the points about choosing a house, doing repairs and arranging your pleasure garden, as well as chapters on household chores, entertaining friends and even recipes for cocktails. Here he has tried to cram too much into too small a space and there are other quite good books on the market which deal much more fully with choosing houses and doing one's own repairs, while household chores and entertaining are subjects on which most people have very strong ideas of their own.

For anyone who is fond of gardening and wants to add something to their pension the information in the second half of the book makes it well worth buying.

C.C.P.

EARTHMOVING MACHINERY—LUBRICATION

(Published by Messrs. C. C. Wakefield & Co. Ltd.)

Messrs. C. C. Wakefield & Co. Ltd. have produced this useful publication to show the importance of selecting the correct lubricants for the component parts of earthmoving machinery. Although primarily an advertisement for their products, this in no way detracts from its value, since it covers the whole subject of plant lubrication in a simple and readable form. The book also contains valuable general information on the care, maintenance and storage of plant.

In the opening chapter the authors examine the reasons for lubrication and explain in simple terms the composition of the more common types of oils and greases. Should the reader have only a basic knowledge of service lubricants, this chapter will do much to improve his understanding of their application. The subsequent chapters are devoted to examining in detail the lubrication of common types of bearings, gears, engines, hydraulic equipment and reeving gear employed in earthmoving machinery.

Each chapter commences with a concise description of the function of the component and goes on to show the importance of correct lubrication, cleanliness and adjustment. The text is illustrated with clear, easily followed diagrams. Some useful hints are given under headings " Storage of Earthmoving Plant " and " Typical Troubles," but the latter chapters are mainly devoted to advertisements.

This book is recommended as a useful guide to those who are responsible for the maintenance of plant, and a similar book by the same firm dealing with the lubrication to road transport vehicles is also available.

M.J.A.

Colonel A. W. Durnford and the Mystery of Isandhlwana

In the April, 1955, issue of the *Army Quarterly* Brigadier-General Sir James Edmonds has written an interesting article on the Zulu War of 1879 with special reference to the mystery of the disaster at Isandhlwana, when nearly the entire force of some 800 British troops were wiped out by the Zulus.

Brevet-Colonel A. W. Durnford, R.E., who was killed in the action, was afterwards held responsible for the disaster, but there has always been a great deal of controversy and many conflicting reports on the subject.

The Durnford family, many of whom served in the Corps, did their best to collect all possible information on the subject. Sir James Edmonds has been able to study these papers and in his article he gives all the known facts in a clear and concise manner. After reading these details one is left in little doubt that the blame should have been laid on others and that Durnford was made a scapegoat.

C.C.P.

TECHNICAL NOTES

ENGINEERING JOURNAL OF CANADA

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

Instrumentation in Armament Development

The R.E. Journal for March, 1955, contained a technical note on the use of instruments for the control of manufacturing processes. This paper discusses the special instrumentation necessary to measure the many parameters affecting armament design and performance. While recent advances in electronics, stimulated by the problems created and solved during and since the 1939–45 war, have almost completely revolutionized instrumentation systems, the task of reducing data to quantitative values is so great as to delay the practical application of test results. This analysis of the problem should be of interest to those who are impatient of delays in production and, with a kindred paper entitled "Photography in armament development", it provides some most interesting examples of modern experimental technique.

Arctic Application of the Heat Pump

This concise and admirably straightforward paper describes briefly the theory of the heat-pump and discusses its special advantages for heating buildings, maintaining water supply at temperatures suitable for pumping, and providing electrical power in isolated installations in the Arctic and sub-Arctic. Although design has not yet reached the stage of absolute reliability, the system proposed seems likely to provide a simple and economical solution to an unusual and difficult problem.

Notes from *The Engineering Journal of Canada*, February, 1955.

Economics of the Nova Scotia Coal Mining Industry

Although this paper contains no technical engineering information, it poses a problem very similar to that which might soon arise in this country and which, while of some technical interest to engineers, is of vital economic and strategic importance. During 1939–45 Nova Scotia coal was of immense value to the Navy and Merchant Navy, just as in this country home-produced fuel is one of our greatest national assets in time of war. Since the war, rapid rail dieselization and the increasing use of hydro-electric power, natural gas, oil and foreign coal have reduced the percentage of Canada's power requirements which are provided by the Nova Scotia coal industry. Since total power requirements have increased, the immediate effect is not critical, but the point has been reached where only increased efficiency and productivity can sustain the local coal industry in the economic struggle against its competitors, while the large capital expenditure involved in reorganization cannot be justified without a great increase in demand. The coal-fired turbine might restore the balance, but its acceptance for railway use is likely to be deferred if complete conversion to diesels takes place before it is fully developed, even though it may prove to be more economical in operation. Meanwhile, what is the future of the Nova Scotia coal industry? What, indeed, does the future hold for British coal?

THE MILITARY ENGINEER

(*Journal of the Society of American Military Engineers.*)

SEPTEMBER–OCTOBER, 1954

"Engineer Shortage and National Security" by Major Lenox R. Lohr.

The author served thirteen years as an officer of the Corps of Engineers, was president of The National Broadcasting Company, general manager of The Chicago World's Fair, and is an engineer and administrator of national standing. His article deals with the critical shortage of engineers now alarming the American military authorities. This year, against 40,000 engineering graduates required in the United States, less than 20,000 were available. This he considers constitutes a threat to National Security, not only by virtue of the shortage it causes of engineer career officers in the Armed Forces, but also by its effect in industry where there is at present a demand for 100,000 more graduate engineers than the existing total of 400,000. In the event of mobilization, this shortage would be serious and would be intensified by the need for at least 20,000 required for the Army engineers alone. By comparison, the author quotes that the Russians have between 1940 and 1950 increased the number of their engineers from 320,000 to 460,000, a greater total than the present American figure. The Russian enrolment in engineering schools in 1950 was 267,000 compared with 180,000 in the United States. One half of the curriculum in Russian secondary schools is now devoted to scientific and technical subjects, and one-third of the students entering college enrol in engineering.

Modern wars are conflicts of technology, demanding more and better engineers in the Armed Forces and in the production of arms. Faced with a potential enemy whose population and natural resources exceed that of the United States, the writer deplores any failure to maintain a clear technological lead and insists that no nation must be permitted to surpass the United States in weapons. Engineers are essential in any race in development and production.

He concludes with an analysis of the reasons for this shortage and makes recommendations for its correction and the build-up in industry of a reserve of engineers for use in war by employing a greater number in the marginal fields, including those of engineer administration.

NOVEMBER–DECEMBER, 1954

"The Military Construction Program", by Brig.-General David H. Tulley, Assistant Chief of Engineers for Military Construction.

An interesting description of the vast works services commitments of the U.S. Army Corps of Engineers at home and abroad, which include, in addition to purely army requirements, some 80 per cent of the Air Force construction programme, as well as work for the Navy, the Atomic Energy Commission, and the Armed Forces Special Weapons Project.

The Corps of Engineers Organization in twelve divisions, with two or more districts in each, is described. This organization, including the two overseas divisions, where the Chief of Engineers has technical staff responsibilities, has commitments in the fiscal years of 1950 to 1955 for a works construction programme totalling £9,004 million.

The author describes in greater detail the work arising out of the Line of Communications agreement with France in November, 1950, to provide a new L. of C. from the ports of Bordeaux and La Rochelle to the American Zone of Occupation in Germany. In this case the organization adopted, without engineering participation, comprised a French Liaison Mission and a United States Communication Zone Detachment with a joint French–American fiscal liaison office. American requirements are presented to the French Liaison Mission for approval and transmission to a French Government construction agency for execution by French contractors. The contractors are paid in francs by the French Construction Agency against dollar reimbursements to the French Government. United States Army Engineers supervise and inspect construction and progress. This did not leave the Corps of Engineers with the effective control of construction operations they desired. Subsequent difficulties described brought out again the important lesson that the engineers concerned should always be included in discussions preceding the conclusion of international agreements involving engineering and construction operations.

News and Comment—"Army Package Power Reactor"

An experimental, full-scale, 1,700 kW. nuclear power plant is to be designed and built jointly by the Corps of Engineers and the Atomic Energy Commission at Fort Belvoir, Virginia. This is the prototype of a "package" or transportable power reactor being developed for use at remote bases to cut out fuel transportation costs. It will also be used for Army Engineer School training purposes. All components of the plant, a pressurized-water type of reactor, will be transportable by air.

CIVIL ENGINEERING

Notes from *Civil Engineering*, December, 1954

Bond and Prestressed Concrete

This is an interesting article on a most important subject and it is very well supported with diagrams and photographs of some very useful tests which were carried out in connexion with this work on bond strength at City and Guilds College and King's College, London. Although the title refers to prestressed concrete, the article is devoted almost entirely to the results of tests on mild steel reinforcing bars in ordinary reinforced concrete. This, in a way, is rather disappointing, as there are a number of problems concerning prestressed concrete with pre-tensioned high tensile steel wires, to which the correct answer is still somewhat obscure. For example, is 0.3 in. the maximum diameter of high tensile steel wire which, when fully stressed, will ensure sufficient bond with the concrete? The author explains that the adhesion between steel and concrete for the transfer of load from one to the other and known as bond, is made up of three components as follows:—

(i) Adhesion.

(ii) Mechanical keying of the concrete in the bar.

(iii) Friction.

The first is a chemical "gluing" between the cement gel and the bar surface, the nature of which is not fully understood. The second and third are self explanatory. The article also mentions that during tests it was found that a decrease in the cement content with constant water/cement ratio resulted in a slight increase in the bond strength, whereas the Code of Practice allows reduced stresses for leaner mixes. From the various tests carried out the author draws the following conclusions:—

For concrete compacted by vibration and having a cube strength of approximately 4,500 lb. per sq. in. at twenty-eight days as follows:—

(i) With all types of bar spacing and arrangement tested the design load of the regulations shows a very high factor of safety.

(ii) The variation in results is small.

(iii) Failure of bond under overload will reduce the load-carrying capacity by about 10 per cent for each bond failure.

(iv) Close spacing of bars will not affect the bond in concrete, which is fully compacted by vibration.

(v) If cracks in beams occur at not less than six bar diameters apart, then it is thought possible that the full load in the bars may be transferred to the concrete between cracks.

Garages for London Transport

The Shepherds Bush garage, designed for 123 buses, is of unusual and interesting design in reinforced concrete. It replaces a fifty-bus garage which occupied part of the site and was built in 1906 (when horse buses were in operation) and subsequently altered to accommodate motor vehicles.

The construction is in reinforced concrete throughout, with brick panel external walls carried on reinforced concrete ground beams. The roof over the parking area consists essentially of hollow reinforced concrete box girders running from the Wells Road entrance to the east end of the garage, a distance of 291 ft. The box girders are carried on a series of main transverse members, which are described as follows in their order from the main entrance:—

(*a*) A deep fascia beam over the Wells Road entrance which incorporates a canopy and with which the box girders are monolithic;

(*b*) Two 99 ft. span bowstring girders in line with each other;

(*c*) A 132 ft. span bowstring girder;

(*d*) A 132 ft. span "I" section beam;

(*e*) A beam and column system at the extreme east end.

Use of Deformed Bars for Concrete Reinforcement

The use of deformed bars for concrete reinforcement has been limited in Great Britain, until comparatively recently, to the use of the twin-twisted and square-twisted bars which, strictly speaking, are not deformed bars at all. This article, which is extremely interesting and well laid out, describes the work which has been done in Canada and the U.S.A. on reinforcing steel of this nature. In the early days of the use of reinforced concrete as a structural material, plain bars only were used for reinforcement. As the deformation of reinforced concrete design progressed, the desirability of bond resistance greater than that obtainable by the plain bar led to the introduction of the now familiar hooked bar type anchorage. The use of this is accompanied by some undesirable features such as:—

(i) The development of bond at a place other than that where the shear giving rise to it occurs;

(ii) The use of extra material;

(iii) Increased fabrication and handling costs.

It was in order to overcome such features as these that the development of the deformed bar has taken place.

The first of these deformed bars, the cold twisted square bar, was patented in 1884 and the early deformed bars were defined and specified by the American Society for Testing Materials (ASTM). It should be pointed out here that by far the greater number of deformed bars in use today have their deformations produced in the original rolling process and possess the same tensile and yield strengths as comparable to plain bars. This is in contrast to certain types of bar in which the deformations are produced by cold working after the original rolling, thereby raising the yield point and hence the allowable working stress. These types of bar may be more expensive than the standard type of bar. The correct use of these bars should be carefully studied, since indiscriminate substitution of smaller areas of bars (using higher working stresses) may lead to excessive deflection in any individual reinforced concrete member.

The article is well illustrated with photographs and tables showing results of tests on bars.

The Pennsylvania Turnpike

There is a long article, accompanied by photographs, of the Pennsylvania Turnpike which crosses the stage from east to west and is an easy grade four-lane, all-weather highway, linking the populous eastern seaboard with the thriving, industrial cities of the Great Lakes region.

Advantages of the Turnpike have been enumerated as follows:—

(i) Safer operation at higher speeds in all kinds of weather.

(ii) Reduced fuel cost.

(iii) Reduced tyre costs due to lower grades and reduced braking effort.

(iv) Reduced maintenance cost, because the lower grades and easy, super-elevated curves result in a lessening of strain on transmission, brakes and engine.

(v) Utilization of lower powered trucks for the same pay load or of increased pay loads for existing vehicles.

(vi) Saving of time ranging from four to six hours over a journey of about 300 miles.

(vii) Reduction of accidents with corresponding savings in insurance rates; and

(viii) Ease of passing trucks and other slow-moving vehicles provided for by an extra 12 ft. lane.

Review of Contractor's Plant

Rotary Air Compressor

The Consolidated Pneumatic Tool Co. Ltd. have put on the market the "Power Vane" rotary air compressor, which is claimed to be the first of its type. It is a four-wheel mounted, fully sprung, portable unit, based on the rotary principle, as opposed to the conventional reciprocating type compressor. Advantages claimed are a reduction in weight by 30 to 40 per cent and reduction in maintenance costs, since the compressor has no pistons, no valves, and no crankshaft. The rotary parts run entirely in oil, which serves three functions: lubrication; cooling; sealing of clearances.

The Rolls Royce engine is a four-stroke, direct injection, water-cooled, overhead, oil engine, with four cylinders having a bore of 5⅛ in. and a stroke of 6 in., giving 110 b.h.p.

Winget-Parsons Trenchmobile

The Winget-Parsons Trenchmobile, manufactured by Winget Ltd. of Rochester, Kent, has been developed to meet the need for a reasonably small machine which will produce trenches suitable for cables, post office conduits and small diameter water or gas mains and be capable of moving from site to site under its own power. The important point about this machine compared with others of similar type is that it has a reduced speed of 12 m.p.h.

Priestman Tiger V Excavator

The Priestman Wolf Excavator with a ⅜-cu. yd. bucket capacity, is a popular machine and well known. Priestman have now produced a new machine known as the Tiger V, which has a ⅝-cu. yd. bucket. The excavator is driven by a Dorman type 4 LA diesel engine developing 57 b.h.p. at 1,280 r.p.m. Two travelling speeds are provided, 1½ m.p.h. for normal use and ⅞ m.p.h. for climbing inclines up to 1 in 4. The working weight of the machine is 14½ to 15 tons. It can be fitted with equipment for use as shovel, trencher, skimmer, dragline, grab or crane.

Rear Dump Trailer

For large earth-moving projects the new Athey PR 21 rear dump trailer specially designed for use with the Caterpillar DW21 tractor would appear to be a very suitable machine. The dump action of the trailer is controlled by Athey three-stage hydraulic hoists, for which power is provided by a hydraulic pump mounted on the rear of the tractor. The makers claim that a heaped load can be dumped from the trailer in 18 sec. This combined with the good top speed of the complete unit, should make for quick handling of spoil.

It has a heaped capacity of 22½ cu. yd. and speeds from 2.16 to 20 m.p.h.

Extracts from *Civil Engineering*, January, 1955.

Quarrying Project at Little Aden

Working under arduous conditions, men of many nationalities from Europe, America, India and the Middle East, have built a large refinery for the Anglo-Iranian Oil Company at Little Aden, together with miles of roads and a harbour which can take the largest ships of the world's tanker fleets. The construction of this harbour and the vast scale of quarrying needed to supply 2 million tons of rock is a story in itself. The contractors were faced with the task of producing a far higher weekly output of rock than is achieved by any quarry in Britain. The work had to start from scratch with a minimum of time for development—normally a most important factor.

The main purpose of the quarrying at Little Aden was to provide rock for the construction of a breakwater 4,300 ft. long and a bund nearly two miles long to contain an area of 200 acres reclaimed with material from the harbour. Of the 2 million tons of rock required for the whole job, roughly two-thirds of the quantity was for the breakwater and bund and the remainder for roads, embankments, aggregate, etc.

The article gives a lot of interesting detail and some excellent photographs of the work.

Research at Universities

This month's edition of *Civil Engineering and Public Works Review* gives a most useful summary of engineering and scientific research which is at this moment being undertaken at the various universities and technical colleges throughout the United Kingdom. The list is complete and gives a good description of the various branches of engineering which are being studied.

The Use of Fly Ash in Concrete

In a previous review attention was drawn to an interesting article on "The Use of Fly Ash in Concrete" and in this month's edition there is a long article supported by facts and figures of work which has been done with this relatively new material.

The rapid growth in the burning of pulverized coal in power stations is making available large quantities of this new raw material in the form of pulverized fuel ash which should be able to contribute to economy and even to higher quality in the production of much of the concrete used in building and civil engineering work. The output of this ash has risen from about 750,000 tons in 1947 to over 2 million tons a year today and is expected to reach some 4 million tons by 1960.

Compressed Air Operation of Earth Moving Plant

The qualities of convenience and safety of compressed air systems and the convenience of installation have long been appreciated in civil engineering and contracting. In fact, the wide and successful use of pneumatics in these applications has been largely responsible for the rapidly increasing developments in many other ways. Compressed air is extensively used in operating tunnelling machinery and aids of all types, and this article gives an extremely interesting description and summary of modern compressed air operated machinery.

Review of Contractors' Plant and Equipment

The French Tower Crane

Jules Weitz Tower Cranes are to be produced at the Chesterfield, Derbyshire Works, of Sheepbridge Equipment Ltd. These mobile electric tower cranes of French design can be rapidly dismantled, transported and re-erected. They are capable of "spot placing" loads of concrete bricks or other building materials from ground level to points several storeys high with the minimum of delay. Compared with borrow-and-plank or hod-and-ladder methods of materials handling on building sites, the Tower Crane is claimed to be capable of reducing handling cost by about one half.

Hanomag Diesel Tractor

The latest addition to the range of earth moving equipment manufactured in Hanover, Germany, by Hanomag Ltd. is the Hanomag K90E. Powered by a D93, 90 h.p. diesel engine, the tractor has belt and drawbar horse-powers of 85 and 75 respectively, the operating maximum drawbar pull being 18,450 lb. The top forward speed exceeds 6 m.p.h. The tractor is fitted with 18-in. tracks with grousers as standard and 22-in. optional. The gauge of the tracks is 65 in. and the weight of the tractor 19,988 lb.

Millar's Weigh Batching Unit

A simple robust weigh batching unit which can be fitted to the standard non-tilt type concrete mixers and will provide an accurate method of proportioning materials without extra plant, is being manufactured by Millar's Machinery Co. Ltd., Bishop's Stortford, Hertfordshire. The principle of this unit is that when the mixer loader bucket is in the loading position it is supported on a track which acts directly on to a hydraulic ram. While the bucket is being loaded the resultant pressure is registered through the ram to a heavy duty indicator dial which progressively records the weight of materials. The dial is mounted on the mixer which can easily be observed.

Notes from *Civil Engineering*, February, 1955

Piles with Enlarged Bases

There is an interesting paper which deals with *in situ* concrete piles which have enlarged bases and are cast directly into a hole bored in the ground without the use of a casing. The space for the enlarged base is provided in a number of ways with different types of piles, but in the case of the experiments carried out in this paper the bases were cut by special knives which were fixed at the end of the drilling tools and were brought into action when the hole had reached the required depth. From the above description it will be obvious that this kind of pile can only be used in cohesive soils and not in soils of a sandy nature. Foundations on such piles are comparatively common in Israel. The article is supported with a considerable amount of data and figures bringing out the important points of this type of pile.

Tidal Energy

On 25th October, 1952, the President of the French Republic at the formal opening of the Donzere-Mondragon plant announced that a tidal power plant would be constructed on the estuary of the River Rance. Tidal power possibilities have always appealed to engineers and practical steps in this direction were taken in 1943 when the S.E.U.M. was set up. Few natural phenomena are endowed with such diversity as the tides. Here are some examples: only one high tide on the shores of Tonkin instead of two on the coast of France; at Tahiti, high and low tides recur every day at the same time and do not lag according to the moon, as in

France. Tidal amplitudes are a foot or so in the Mediterranean and of over 43 ft. in the Mont Saint-Michel area. The article goes into the theory of this natural energy and how it can be economically harnessed.

Air Tight and Water Tight Rock Chambers

The varying conditions of bedrock particularly with regard to freedom from cracks, constitute a difficult problem in trying to find a reliable and economical solution to the planning of bedrock projects. This applies particularly to the possibility of estimating the cost of maintaining dry air in the future in rock chambers. The work of sealing rock is made difficult by the fact that the operation is carried out on the low-pressure side and frequently with water soaked surfaces. The article goes into this question in detail and gives examples of several underground shelters which have been treated in this manner in Sweden.

Review of Contractors Plant and Equipment

Fork Truck with Swivelling Mast

A new fork truck is being manufactured by Ransomes & Rapier Ltd. The machine, known as the "12/24 Super Fork Truck", has been designed to handle long loads such as steel sections, pipes, timber, etc. and has been provided with a mast arranged to swivel to one side, thus enabling the load to be carried in line with the direction of travel of the truck. This is a most important feature. The machine has four motions: travel, hoist, tilt and slew. The truck is powered by a Perkins P6 diesel engine developing 70 b.h.p. at 2,000 r.p.m. The machine has a lifting and carrying capacity of 12,000 lb. at 24 in. from the face of the forks. Road speed, top gear, 20 m.p.h.

Small Diesel Dumper

A new four-wheel 15-cwt. dumper known as the "Roughrider" has been put on the market by Liner Concrete Machinery Co. Ltd. The fuel consumption is quoted as about two gallons of diesel oil per working day. The maximum unloaded speed is 12 m.p.h. and the loaded speed 4 m.p.h. The heat capacity of the hopper being 18 cu. yds.

CORRESPONDENCE

CONSTRUCTION PLANT IN NUCLEAR WAR

To The Editor, Civil Engr. School,
The R.E. Journal. S.M.E., Chatham.
Dear Sir, 27th April, 1955

Some interesting articles on possible conditions in a future nuclear war have appeared recently in the *R.E. Journal*, for which the contributors must be given full credit for careful and chosen thought on a tiresome but serious problem. Most of the engineering difficulties predicted and possible solutions follow a logical sequence of thought; it is only when construction plant is considered that there is a grave danger that we are about to be led up the garden path—possibly close behind the drawbar of a "Bunkum Digger" or similar gardening tool.

We learnt the plant lesson towards the end of the last war and during the reconstruction period, and as engineers we must ensure that constant reminders are provided. Plant which is to be employed on extensive tasks must be large, heavy and powerful. The United States Engineers have implemented this lesson in full, so have our own experienced and powerful civil engineering industry; we too should equip all our engineer units with heavy plant on a formidable scale.

The wheeled tractor has, without doubt, proved its worth in agriculture and, fitted with various types of mechanical handling equipment, a number have been used with some success on housing estates, in builders' yards and in factory areas where reasonable hardstanding exists. They have not, however, been generally accepted by the civil engineering industry and there have been a number of dismal failures reported from sites where these machines have been put to work. This is not surprising, as they are competing against machines which are basically designed for this type of work. The mock-up wheeled tractor is not so designed. It is, in fact, when compared with conventional plant, an inefficient and uneconomical machine. Few will disagree that the adequate supply and economy of fuel will be vital in the next war. We should note, therefore, that the operation of these inefficient machines would result in more than twice the fuel consumption required for plant of conventional design. A few figures will make this clear:—

The average output of a 35–40 b.h.p. tractor/digger in average soil is 16 cu. yds. per hour at 2 gallons per hour fuel consumption. The output/fuel ratio $\frac{16}{2}$, i.e., 8 cu. yds./hour/gallon. That of a 130 b.h.p. tracked excavator under similar working conditions is 110 cu. yds. per hour at 6 gallons per hour, i.e., 18 cu. yds./hour/gallon.

This is for digging. The inefficiency of these machines reaches even greater proportions for dozing, scraping and general clearing work and in hard, tough ground or very heavy wet soil, they are more or less useless. For other engineering tasks, e.g., heavy bridging, these machines have awkward limitations. It is undesirable and certainly not a practical proposition, especially at night on a difficult site, to have a machine which can lift a Heavy Girder panel only 3–4 ft. clear of the ground, apart from the inability to luff or slew. It is claimed that the wheeled tractor type machine is cheap to produce and easily obtainable. When considering this fact, its meagre output must be remembered.

It is not generally realized that a number of firms are now producing quantities of heavy plant in the United Kingdom. We are no longer dependent for either machines or spares from "lease lend".

There are two questions over which the nuclear strategist will worry. These can be answered now. How shall we be able to move this heavy plant?

The movement of heavy plant is a mythical staff worry. It can be moved, it was moved in the last war, it could be moved in the next. A heavy machine has as much chance of moving from A to B in nuclear warfare as any other equipment in the army, in fact more so, as it can clear its own route through devastation, or travel cross-country towing its own transporter. The excessive movement of heavy plant is the direct result of shortage and could be avoided by adequate deployment. If one engineer unit is to be replaced by another, then the plant should stay put, a simple hand-over taking place at each location.

How shall we be able to maintain heavy plant?

A maintenance problem, as we have known it in the past, will not exist, nor will similar logistical worries, because active nuclear warfare will only last for a period of weeks, not years. Maintenance problems during the long clearing up period will solve themselves.

The task of divisional and corps engineers may be on a scale similar to and just as heavy as that of engineer units behind them. The adjectives "divisional" and "corps", when applied to engineer organization, will cease to have the same meaning as they have had in the past and there will be neither the resources nor the time to go running about the countryside on agricultural tractors digging holes for other arms. The Allis-Chalmers Co. are importing to U.K. their new HD21 crawler tractor, the engine develops 235 b.h.p. and a drawbar pull of 65,000 lb., i.e., a very much more powerful machine than the war-time D8. It was pointed out recently in the *R.E. Journal* that in nuclear warfare we shall have another problem to face—that of national survival as distinct from functioning. The existence of this type of machine in quantity may well be the deciding factor as to whether survival on a post nuclear war earth is possible.

Yours faithfully,

G. T. Fitchie, *Major R.E.*

ARMOURED FIELD ENGINEERS

School of Tank Technology,
Bovington Camp,
Wareham, Dorset.
25th April, 1955.

The Editor,
The R.E. Journal.

Dear Sir,

General Martel's letter on Armoured Field Engineers in the March *Journal* raises issues of great interest to those of us who are concerned with any aspect of the development and employment of armour.

I believe that only a comparatively few R.E. officers appreciate the great difference between working *with* armour and working *in* armoured fighting vehicles. The techniques of command and control, and most of all those of maintenance, are not easy to acquire and it is most important that a reasonably large body of really well trained officers and N.C.Os. are available within the Corps at any time.

It is quite possible that the necessary techniques and attitude of mind can only be acquired by officers who serve in A.F.Vs. for the greater part of their service, in exactly the same way as do officers of the Royal Armoured Corps. It must be remembered that future A.Vs. R.E., like modern fighting tanks, are likely to be much more complex than those of the past.

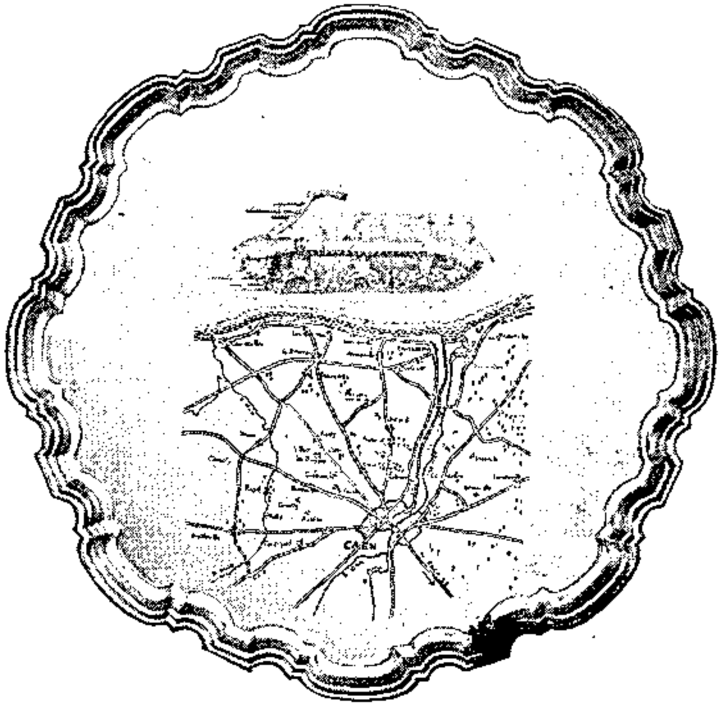
In the first stages of a nuclear war it will not be possible to retrain ordinary Sapper officers as "armoured" Sappers, and it is highly improbable that the R.A.C. will be able to spare officers already trained in armoured warfare. Even if the R.A.C. could do so there would not be time to give even the most elementary Sapper training to them.

General Martel has suggested that a much higher proportion of Armoured Engineers may be required in a nuclear war, and all those who have had the opportunity of studying the problem must surely agree. The mobility and usefulness of unarmoured units in forward areas will be severely reduced and, in the case of ground burst atomic weapons, unarmoured Engineers with armoured formations would be quite unable to go forward with the tanks over contaminated areas.

I would suggest in conclusion that the time has come when a much higher proportion of R.E. officers should obtain really detailed knowledge and experience of modern A.F.Vs.

Yours faithfully

A. A. T. Hiscock, *Major, R.E.*



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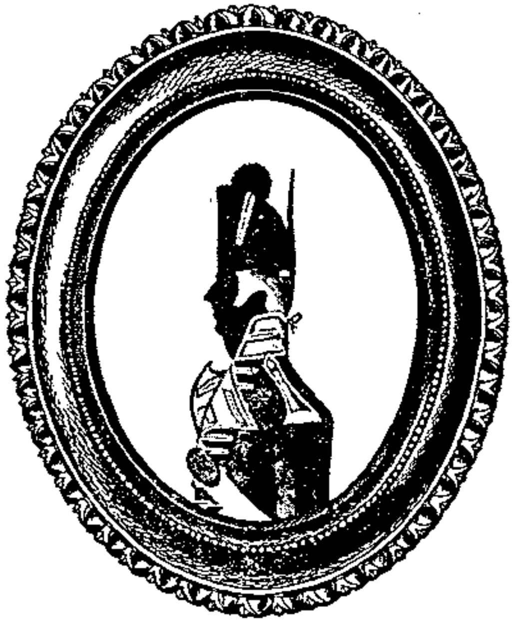
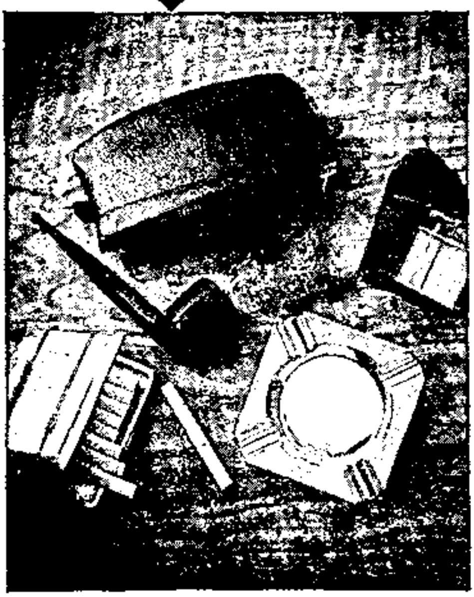


from Tea

to Tobacco



A cigarette and a cup of tea—two of the minor pleasures of life, but such as few would be without. This is as true of the members of Her Majesty's Forces as of most of us.

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