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Photo 1.—Meade's Col and the summit of Kamet from Camp IV.

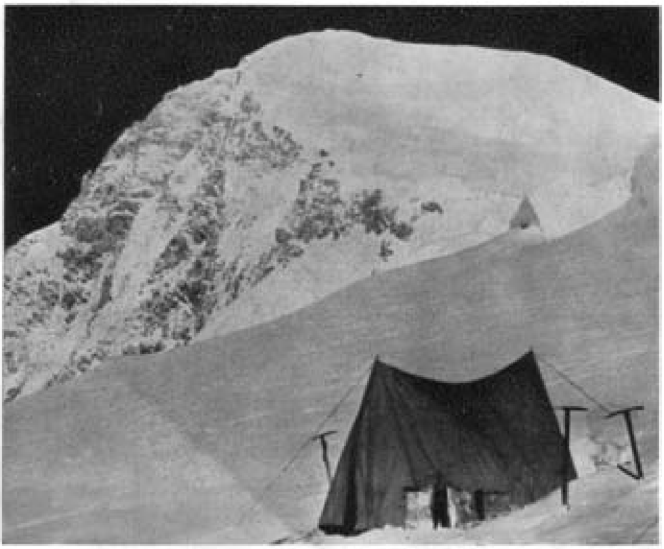


Photo 2.—The summit from Camp V.

Attempt to climb Kamet 1,2

ATTEMPT TO CLIMB KAMET

By Major-General H. Williams, C.B., C.B.E., M.I.C.E., M.I.E.

(Reprinted with the permission of the *Times of India*)

Preparations for the Expedition

KAMET (25,447 ft.), the second highest mountain in India, is only 200 ft. lower than Nanda Devi. Thus the decision to attempt it last year was not lacking in boldness, particularly as the main object was to introduce some young officers to mountaineering. Two of our party, Gurdial Singh and Nandu Jayal, had, however, climbed high the previous year, Gurdial Singh to the summit of Trisul (23,406 ft.) and Nandu Jayal with the French Expedition to about 23,000 feet on Nanda Devi, and they were anxious to go higher.

A further object was to prove that a sizeable expedition could be mounted in India and that attempts on the higher peaks need not for long remain the monopoly of visiting expeditions. Smythe's account of his party's successful attempt in 1931 and advice from Mr. Holdsworth who reached the summit then, led us to believe that, given luck in the matter of weather and in finding a way up the difficult rock climb from Camp III to Camp IV, we might make a fair bid for the summit.

Our first problem was that of equipment, stores and transport, or to put it more concisely, that of funds. Climbing in the Himalayas is expensive, and this hard fact must be faced by every youngster who wants to climb there. We were not altogether without sympathizers. We thought that those in authority showed a breadth of vision altogether in keeping with the importance of our plans, and leave, to which I was not entitled, was sanctioned without hesitation. Army Headquarters appeared to stop all other work in order to provide us with such tentage, equipment and medical stores as could be made available, and the Bengal Sappers who sponsored the expedition, met our unending demands with enthusiasm. There were other benefactors too. One generous firm provided all our biscuits and sugar, and another all our jams and tinned vegetables. The way to the summit is marked by the paper wrappers of another firm's confectionery, and the Transport Company provided us with a free bus for our drive through Garhwal. In this manner our ways and means problems were greatly eased.

Our party was stationed at different places and we did not all meet till we reached the Forest Bungalow at Kotdwara, so planning presented some difficulty. We appointed different members to look after equipment, messing and transport, and nominated a secretary and a treasurer and then by the issue of comprehensive instructions hoped that each would play his part. We roped in helpers to purchase equipment, to knit pullovers and socks, to purchase and pack food, to make and bottle chutneys and to select our Sherpas at Darjeeling. Finally when the mountains of equipment, clothing and food were assembled at Roorkee on 2nd June, we felt that very little attention had been paid to Shaw's *obiter dictum*. "The more a man possesses over and above what he uses, the more careworn he becomes" and we had to do a considerable amount of discarding and reorganizing.

Journey to Base Camp

The journey to the Base Camp was straightforward and strenuous. Two days by bus brought us to Chamoli and two days marching along the pilgrim route, to Joshimath. Here we were met by Kesar Singh, a Bhotia from Upper Garhwal. He had accompanied Smythe's party in 1931 and accomplished the astonishing feat of climbing from Camp III to Camp V in one day and to the summit on the following day. The years have not dulled his enthusiasm or his capacity for bluff and he swore to us that he would reach the summit or die. He did neither, but he helped us to engage porters and alternatively amused and exasperated us.

At Joshimath we engaged a Tibetan Sikh to transport our forty maunds of baggage and stores in five marches to Niti, the last village in India along this route to Tibet. From various points of vantage along the road we had wonderful views of many great Himalayan peaks including Nanda Devi, Dunagiri and Hathi Parbat, some of which still remain to be "conquered."

We rested for a day near Niti while Kesar Singh collected jhobas, ponies and porters and bargained with us about wages, food and clothing. Next day we set out for the Base Camp two marches away. We crossed the Dhauliganga by a snow bridge still strong enough to take unladen animals, and found ourselves rapidly leaving all vegetation behind. Finally we passed the last stunted juniper trees and pitched camp at 15,500 ft. Tent plinths, some rusty tins and a pipe cleaner were sufficient evidence that Smythe and his party had camped in the same place twenty-one years before. From here, when the clouds lifted we had our first satisfactory view of Kamet, and here we separated essentials from luxuries, and reorganized our baggage into suitable man loads.

Our task now was to establish five camps up the East Kamet Glacier and on to the Kamet ridge culminating in Camp V, just below Meade's Col. This was clearly a nice problem in logistics. No camp is safely established unless the occupants have fuel and food for at least three or four days so that if the weather becomes bad they can withstand a siege. Porters must carry food and clothing for their own needs, and the residual quantities available for stocking are not great. Inevitably several days must be spent at each camp, but this helps acclimatization. We took twenty-three days to complete the journey from Roorkee to Camp V—an average rate of climbing of about 1,000 feet a day and this is the least advisable figure at which to aim.

Shortly after leaving Camp I we entered the narrow gorge where forty-five years ago Longstaff and his guides turned back because they judged the danger from avalanches too great. The north face of the Mana-Deoband group to our left was heavily plastered with hanging glaciers, and from time to time huge blocks of snow and ice broke away and tumbled into the main glacier. Before us like a gigantic screen stood Kamet bounded on the right by Abi Gamin and on the left by Mana. Every problem of the climb showed up; the long pull up the gulley to Camp III, the difficult rock climb to Camp IV, Meade's Col. at 23,500 ft. near which Camp V must be established, the long slope to the summit and the final steep 500 ft.

At Camp III we suffered our first casualties. Mark Valladares was continually and violently sick and Nalini Jayal suffered from headache and giddiness. Altitude sickness is attributed to a lack of oxygen in the system, but it is difficult to explain why it affects some people and not others. Nalini had flown at heights up to 40,000 ft. using oxygen, and Mark had been first into camp all along the journey. Yet after three days at 20,500 ft. they were completely exhausted and had to give in. Several porters whom we hoped would go high also went sick and the consumption of aspirin rose rapidly. Once invalids descended to Camp II they recovered completely.

Then followed two days reconnoitring the difficult route between Camp III and Camp IV. The careful briefing we had received made it easy to discover the way ultimately chosen by Smythe and his party, and a great shout of joy went up when some pitons and rope left behind in 1931 were found. Fresh ropes were fixed along the difficult sectors and the route up the rocks made safe for laden porters.

Attempts to Reach the Summit

Gurdial, Nandu, Johorey, and Bhagat were chosen to make the first attempt and they left next morning with four Sherpas and six Bhotias. It was a long day ending with some three hours of step cutting on the ice slope above the rocks, and we watched them anxiously from Camp III. Late in the afternoon we were greatly relieved and delighted to see them disappear one by one on to the plateau above. Camp IV had been established.

Next morning Bhagat complained of not being well and said he would follow later. He and a Sherpa remained behind while the others set out in gathering mist to establish Camp V. The party was soon in difficulty among seracs of fallen ice and in danger from crevasses. They were carrying heavy loads, the climbers 30 lb. each and the porters up to 50 lb. Gradually the going changed for the worse, the mist completely enveloped them and it began to snow. Then fearing that their tracks would be completely obliterated and that the porters returning that evening might lose their way, they pitched Camp V at about 23,000 feet, unfortunately some 300 feet lower than Smythe's party had done.

All night long a violent wind buffeted the tents, and the next day was cold and misty and they were able to do little. One of the Bhotias, Kalyan Singh, however, escorted a sick companion back to Camp IV and returned again in the afternoon. Manohar Lal and I climbed to Camp IV where we found Bhagat still far from well, but anxious not to give in. The morning of 26th June, was fine and clear but still cold. The assault party, now reduced to three climbers, two Sherpas and the Bhotia, Kalyan Singh, made their first attempt. They took it in turns to lead, changing over every twenty minutes. The snow was soft, they were hampered by crevasses and progress was very slow. By 12.30 p.m. after four hours' climbing they had only ascended about 1,000 feet. Several of them complained of cold and signs of frostbite. After some debate it was decided to abandon the attempt in the hope that the tracks already made would make a subsequent assault easier.

Manohar and I met them on their return to Camp V and it was decided that they would remain there for at least two days more and make a further attempt when the weather permitted. I then returned to Camp IV as Bhagat showed no signs of getting better. That evening he told me that he had stumbled in the snow some days before and struck the point of the ice axe into his leg. At the time he thought the wound trivial but it had now gone septic. Though it was small and apparently not very deep, it was full of pus and he was running a temperature.

The next day was one of mistakes and frustration. It was snowing hard in the morning and it took nearly two hours to boil sufficient water for breakfast. Gradually the weather improved and early in the afternoon we began to move Bhagat back to Camp III. We had not gone far when it became obvious that he could not make the descent and that he would have to be carried the whole way down. Meanwhile at Camp V Nandu and Gurdial unaccountably developed a desire to scale the lower Abi Gamin peak and lost sight of the possibility of moving their existing camp some 300 to 500 feet higher up.

The following day was brilliantly fine. Unfortunately the fresh snow had completely obliterated the tracks of the previous attempt and the whole process of prodding for crevasses and stamping out

Photo 3.—Camp I with Mana (23,860 ft.) and Deoban in the background.

Photo 4.—Camp II. Kamet in the background (white peak on left of photo.) and Meade's Col in the centre.

Attempt to climb Kamet 3,4

Photo 5.—Camp III showing the difficult rock climb to Camp IV.

Photo 6.—Meade's Col from Camp IV.
Camp V was in hollow at foot of steep ascent on left of photo.

Attempt to climb Kamet 5,6

tracks had to be done over again. Shortly after midday Nandu who was roped with the two Sherpas, Ang Dawa and Ang Temba, felt that he could go no further, and turned back.

Gurdial with Kalyan Singh and Pembu Norbu carried on, hoping at least to reach some rocks which stood out above the snow on the edge of the precipice. They gained height but only very gradually as the snow conditions got worse and they were sinking in up to their knees. About 3.10 p.m. when they were about 600 feet from the summit Kalyan Singh gave in. The remainder of the climb would have taken another three hours and Gurdial felt unable to lead for long, and so they turned back, finally reaching Camp about 5.20 p.m.

The Return Journey

Next day after spending five nights at Camp V they returned in a very exhausted state to Camp IV. That other bugbear of high climbing had begun to tell, and they were clearly suffering from the deterioration which living at high altitudes gradually causes. Bhagat's wound was slightly better but he was still weak and unable to walk. We therefore improvised a sleigh using Nandu's skis and ice axes, and lowered him down the ice slope. We worked continuously and under great tension as a slip would have meant disaster. Then followed the climb down the rocks, porters and climbers carrying him in turn over ground where a mistake would have been fatal. Very tired indeed, we reached Camp III as the light was failing.

The next three marches back to Base Camp were strenuous but we were descending and they would have been very enjoyable but for our anxiety about Bhagat. His temperature had dropped and in some respects he appeared to improve but he was still weak and listless. We hoped to get him back to hospital at Joshimath and planned to double march as soon as we reached the easier going of the trade route. But during the night at Bampa, to our great sorrow and distress he died in his sleep. So passed a very keen and companionable young officer who showed every promise of being one day a fine mountaineer. We assembled some hours later on the bank of the Dhauliganga and there his body was cremated. Then we marched back to Joshimath and on to Badrinath and immersed his ashes in the sacred waters of the Vishnuganga.

So ended an expedition which, though it did not succeed in "conquering Kamet," gave its members wonderful experience in living hard and climbing high. It has shown that given help and encouragement there are plenty of young men in the country who can climb high, and we hope that it has shown young men that if they want to climb high, help and encouragement will be forthcoming.

Causes of Failure

We have since discussed the causes of our failure to reach the summit with Mr. Holdsworth and these are our conclusions.

Smythe's party had a much stronger team of Sherpas and Bhotias and the climbers who reached the summit carried no load other than spare clothing and cameras, whereas our assault party carried some thirty pounds each.

We spent too little time acclimatizing between 18,000 and 20,000 ft. Smythe's party spent some four days at Camp II and seven days at Camp III, compared with our total of five days at both camps.

They had unbroken fine weather from 2nd to 23rd June and as a result the snow was reasonably firm up to the last 500 ft. We, on the other hand, were sinking in up to our knees in many places above 22,000 ft. They had a windless day for their final assault: we were not so fortunate.

Finally, we were not so experienced a party and we made many small mistakes about equipment and food for use above 20,000 ft., but we shall not repeat these next time!

Those who would like to read about Smythe's successful climb will find an excellent account in his book *Kamet Conquered*.

THE BEHAVIOUR OF RIVERS

By Colonel Sir Gordon Hearn, C.I.E., D.S.O., A.I.C.E.

THE interesting article by Major Lawrie in the September, 1952, number of the *R.E. Journal* induced me to look up papers in the Proceedings and Journals of the Institution of Civil Engineers, beginning with three papers read in the session of 1923–4, of which I contributed one. This dealt with small catchments of an area up to about twenty square miles, quite capable of discharging a river, but not of the size perhaps contemplated by Major Lawrie. A large number of observed discharges were cited and it was sought to show that the shape of the catchment is a factor in producing violent floods much greater than might be expected from the amount of rain falling, heavy though it might be at some time and on any catchment in any part of the world. There are many factors affecting run-off as stated in Appendix "A" to Major Lawrie's article, but it is the shape which causes a concentration at the confluence of the drainage.

There have been two instances of disasters in the last thirty years or so in this country, where long immunity has blinded foresight of the potentialities of such catchments. One was at Louth in Lincolnshire in 1920 when people in the ground floor rooms of houses, built almost in the river bed, were drowned with their heads against the ceilings. The other occurred last year at Lynmouth and is still under investigation, but a glance at a map shows that the catchment had dangerous possibilities.

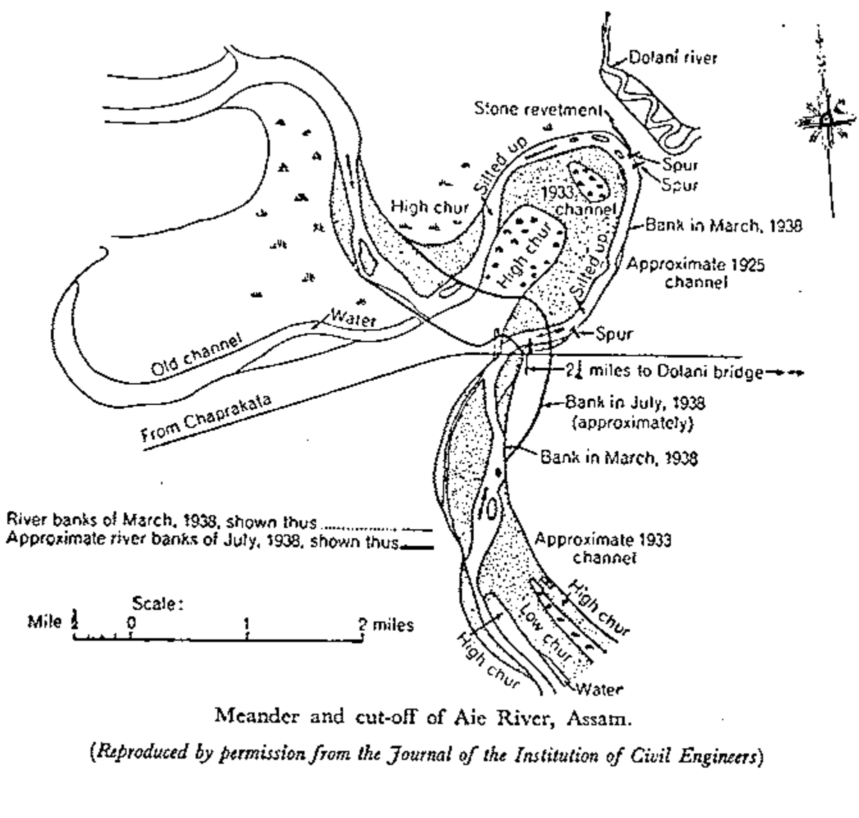
Such cases are of interest to military engineers in the prevention of flooding of camp sites and dips in major roads. Remedial measures consist in delaying concentration of the run-off. *The Saturday Evening Post* dated 4th August, 1951, describes what was done in Oklahoma in a catchment of six square miles, feeding the Washita Creek of the Red River, resulting in the confinement between its banks of the run-off from 13 in. of rainfall in 24 hours. Two quite small retarding basins and two small dams had been built, but in addition, the slopes had been "contour-ploughed" or terraced, "defeating each individual floodlet before it could get started." Similar treatment in another case was successful, but a mile below the treated and "tamed" portion the stream had received sufficient water to overflow its banks. The co-operation of farmers would be required but the treatment could do their land no harm, and might lead to marginal culture.

In the case propounded by Major Lawrie, such measures are impossible, and it is very important to arrive at a close estimate of the discharge, a matter discussed in a second paper by Mr. G. E. Lillie with many illustrations, and, for those who revel in mathematics, one by Mr. Griffith in 1937, at the Institution of Civil Engineers. When I began a long experience in railway surveying, the instruction was to take a cross-section of the bed at the proposed site, another at a mile up-stream and a third a mile down-stream. The two last will give the fall in surface slope, which could be combined with the wetted perimeter to give the velocity and possible scour of the bed below which the piers must be founded at a safe depth.

The most reliable information for taking levels and cross-sections can be obtained at villages up and down stream and the rest is only a matter of denominator to determine the slope (S) at the highest flood stage, when the overgrown island shown on the cross-section, at page 259 of the *R.E. Journal*, taken in the dry season, has been submerged. If the whole area (A) is divided by the wetted perimeter, the result may well be a too small hydraulic mean depth, and it is better to measure first the two areas and wetted perimeters, one in the main channel and the other over the partly silted loop, when the water level is just topping the high island. The discharges added together will, of course, be exceeded in the highest stage, when the total discharge can be calculated in three parts, as partly indicated on page 262 in Fig. 5, exaggerated in depth. Manning's formula can be used, though Mr. Gerald Lacey considered the Kutter coefficient to be unnecessarily complicated.

At best, the result will be only an approximation, for the water surface may not be level from bank to bank and there will be bed scour of the silt dropped by the falling river, which then meanders still more in its bed. At this time low islands are formed, pear-shaped with the stalk down-stream, but, if any are shown on the cross section, they will be swept away by the rising river. The formula of Mr. Gerald Lacey, simplified, may be used to calculate the bed-scour from which the vegetation will protect the high island.

The impression is given on page 260 of the *R.E. Journal* that a change of course described by Sir Francis Spring takes place every year, but it may take a long time. A cut off appeared to be imminent in 1925 in the Aie river in Northern Bengal, but it did not occur until 1933 to a small extent and a complete change of course came five years later, with great violence. The changes in course of this river are shown in the sketch below.



Meander and cut-off of Aie River, Assam.

(Reproduced by permission from the Journal of the Institution of Civil Engineers)

Any relatively small margin of error is not likely to be corrected by the use of any formula based on area of the catchment, even if the country is well-mapped and the geological conditions are known. The famous formula of Colonel Dickens was the result of only four observations of discharge from catchments varying in size from 80 acres to 27,000 square miles in South Bihar, where the rock is plutonic. In one of the three papers mentioned earlier, Mr. Glass examined the case of the Damodar river, which has been gauged continuously since 1857 and 1909 at two points, with highest floods seldom exceeding 400,000 cusecs. Colonel Dickens much under-estimated the area, which once, in 1913, discharged 650,000 cusecs. The difficulty of selection of a coefficient ranging from 400 to 800 is enhanced by the adoption in other parts of India of coefficients to the formula, ranging up to 1600, while retaining the same index to the power of the area in square miles.

It is time now to examine the Inglis formula based on the meander length between node points at which the river alters its course. It must first be remarked that the measurement of the length must be extremely accurate, for if it be 27,000 ft. the discharge will be a million cusecs, and if half that length "Q" will be only a quarter. Having held charge of bridges on the Eastern Bengal Railway for some years and having observed the behaviour of many meandering rivers I endorse the principle, but consider the application of the formula very difficult. From his experience as Chief Engineer of the North Western Railway of India, Lieut.-Colonel W. Macrae would probably agree.

A meandering river behaves like a snake slithering down a slope and eroding the soil at each bend, but if some hard stratum is encountered the meander length is squeezed between nodes and the main channel lengthens to form an embayment above the obstacle, which may be the head of a guidebank or outer defence. The curvature of this embayment is sharpened until the river may almost turn back on itself when a cut-off will occur across the peninsula and the whole régime will be altered on the opposite tack. The ratio of length round the bend to the length of cut-off may vary from one and a quarter in the Lower Ganges to as much as four in a smaller but very obstinate river. The embayment is a symptom of approaching change of course and is readily noticed when fixing a provisional site for a bridge.

It has been suggested that a great increase of sinuosity is a symptom of a dying river and it is true that water in a series of rivers running side by side from the foothills of the Himalayas may spill over from one to the next, but the reverse may take place in a later year and it is not safe to anticipate an early demise. It is advisable to select a site at right angles to the main axis just above an incipient embayment, to make use of the high island, and to span if possible the main channel and old cut-off, being prepared to launch forward or re-erect the long spans. The nature of piers founded alongside deep water can be decided by the Bridging School, but they must be quickly driven down and their grip in the bed should be one half of the height from the scoured bed to the bed-plates of the girders.

The use of stone to prevent scour round piers is a very moot question, but it would seem better to let the bed scour to a regular profile. Instances can be given of weirs becoming developed over a series of years and, in one case, of a stone bank being built for the erection of a span with bad results later. The sources of stone for armouring guide banks in large quantities may be distant and priority for bringing it up may be refused.

It is not likely that any engineer, civil or military, will be asked again to bridge a river like the Lower Ganges at the Hardinge Bridge, built 1909–15 by the late Sir Robert Gales, who described in the *Journal of the Institution of Civil Engineers* for 1938 various mishaps in the intervening years. The bridge was not built at right angles to the main axis, but there were many factors in coming to this decision, one of which was a real fear that an upset to the régime might result in the sweeping away of Calcutta. In engineering matters the layman is hard to convince.

The Ganges at the Hardinge Bridge is a meandering river and its meander length is difficult to ascertain, but to judge from a cut-off it may be ten miles. The Inglis formula would give a discharge of 4 million cusecs, but the greatest observed does not exceed 3 million, with a surface velocity of 13 ft. per sec. and a depth between piers of 95 ft. At low water it is difficult to keep open a channel 6 ft. deep for the navigation of flat-bottomed river steamers. Incidentally the bridge is now in East Pakistan and the sources of stone supply are in India.

Reverting now to the Aie River the discharge was estimated in 1925 to be 16,000 cusecs which may have been an under-estimate but the cut-off of 1938, or meander length, measured just over two miles, about the same as the length of the Jumna at Delhi given in Table "B" of Major Lawrie's article. The discharge by the Inglis formula would be of the order of 250,000 cusecs and this is inconceivable. It does not seem that the "marriage" of the Inglis and Gerald Lacey formulae can be justified. It may be mentioned that the provision of an "echo sounder" for the Hardinge Bridge was recommended in 1925, but did not materialize until 1934.

A FORGOTTEN BATTLE—EL OBEID

By MAJOR-GENERAL B. T. WILSON, C.B., D.S.O.

THOSE whose pleasure or business it is to write about battles seldom want for material on which to base their work. Indeed the writer will often find himself embarrassed by the rich variety of evidence, which seems only to await a master hand to change it into a noble story.

But in this forgotten battle, which was an important one, the testimonies of only two men throw much light on what actually happened—one was a batman ; the other was a cook. The batman was one Gustav Klootz from Berlin. He had been an under-officer in the Uhlans of the Prussian Guard and his flair for unfavourable military situations caused him to go over to the enemy before the battle joined. But it did not avail him much, for he died three years later, miserable and dishonoured, whilst trying to escape from captivity. The other eye witness was Mahomed Nur el Barundi, the General's cook. He was the sort of cook that rich men and princes employ and like most cooks who accompany armies in the field, he was a stout-hearted man. In the battle he was severely wounded and left for dead in a thicket but he crawled out after the tumult was over and became a prisoner. After six years he escaped and told his tale.

Before the battle the army to which these two men belonged was nearly 10,000 strong. After it was over only a few hundred wretched prisoners were left alive ; everyone else was dead. It was Hicks Pasha's Army of 1883 which had been sent to the Sudan to suppress the rebellion of Mahomed Ahmed, the so-called Mahdi.

Mahomed Ahmed was one of those remarkable men capable of inspiring fanatical enthusiasm, who crop up from time to time in history usually bringing dire harm to their fellow men. His family came originally from Dongola in the north, but moved when he was still young to the island of Abba on the Nile about 160 miles south of Khartoum. They were boat builders, so that Mahomed Ahmed was clever with his hands. But he was more interested in the Koran than in the family business and lived the wandering life of a Dervish. He was a man of average height with a full-lipped, bearded face which was extremely dark for an Arab and scored with three tribal marks on each cheek. His teeth were of ivory whiteness with the two front ones separated into a V. This V became famous, as did a mole on his face, for the Prophet Mahomed had had them too. But it was his benign smile which impressed the onlooker most and helped him to gain so many believers in his claim to be divine.

Women in particular worshipped him, nor was he averse to their attentions. In his early days, however, ascetic and thin, he stressed the more austere teachings of the Prophet and inveighed loudly against such worldly entertainments as dancing girls and boys in fine raiment at religious festivals. Such austerity was displeasing to the holy men of Khartoum so that Mahomed Ahmed fell foul of them and had to withdraw to the boat builders at Abba. Here he lived apart in a cave, learned the Koran by heart and dreamed.

But his fame was spreading throughout the country. Abdulla, the great chief of the Baggara Arabs, came on a pilgrimage to Abba, where he fell very sick of fever. Mahomed Ahmed came to visit his distinguished guest at the crisis of his illness. To Abdulla in his fever, the visitor in his shining white robes looked like a god. Moreover he suddenly felt strong and well and convinced that Mahomed Ahmed was the expected Mahdi. Without more ado, he placed himself and his great tribe at the Mahdi's disposal.

After this, events moved fast. Troops came by steamer to Abba to destroy the Mahdi and his followers but acted half-heartedly and were all killed or driven off. Imitating the Hejira of the Prophet, the Mahdi then fled to a hill in the Nuba Jebels south of El Obeid and proclaimed a holy war against the " Turks " and unbelievers, who were oppressing the Sudan. Slave traders and malcontents of every kind flocked to his black banner.

Abdulla became the Mahdi's chief Khalifa and Army Commander. Together, with a great multitude they moved in dusty clouds on El Obeid, the capital of the Korthofan provinces and after a vain attempt to take the town by storm, laid siege to it and starved it into submission. Six thousand rifles, five guns, much ammunition and 100,000 pounds in gold fell into their hands. They began to dream of capturing Khartoum and Cairo and of conquering the world. Cruelty and lust also raised their ugly heads in the Mahdi's camp. The Khalifa specialized in cruelty, whilst the Mahdi added to his harem from the women of many races captured in El Obeid.

Egypt, the suzerain of the Sudan, which then extended as far south as the great lakes of the Nile, lay nearly 1,000 miles to the north of the events which were taking place at El Obeid. The Nile spanned the burning sands of the Nubian desert but its cataracts were a hindrance to river traffic and so was the tedious backward bend of 600 miles between Abu Hamed and Wadi Halfa. Troops and travellers for Khartoum usually went by the Red Sea to Suakin and thence to Berber and the Nile. But there was, curiously enough, a telegraph line from Cairo to Khartoum and even on to El Obeid. It preened itself, then, on being the longest telegraph line in the world.

Egyptian affairs were in a bad way. England and France had already taken over control of finance when, in 1882, Arabi Pasha staged a *coup détat* with the Egyptian Army. Mr. Gladstone, much against his will, had to take action to safeguard European lives and property and landed a small British force in Egypt. Rather to the mortification of France, who had stood aside, and to the astonishment of Europe, the small British force defeated Arabi Pasha's army at Tel el Kebir in forty minutes and occupied Cairo the next day. Upon this the military pundits talked rather pompously about modern weapons of precision and the advantage they conferred on civilized troops fighting against savages. Why not have another forty-minute battle against this Mahdi rebel who had bobbed up in the Sudan? But Mr. Gladstone refused point blank to send British troops up the Nile and said that the Sudan was the Khadive's affair not England's.

There was, however, no lack of military gentlemen looking for adventure. Amongst them was Lieut-Colonel (Hon. Colonel) Hicks, a retired officer of the Indian Army. He was a capable soldier with a good record in India and Abyssinia and above all he was an Englishman. For a brief period after Tel el Kebir, all British officers were military wizards. Hicks Pasha was 53 years of age and in those days of mutton-chop whiskers and Piccadilly weepers, contented himself with an imperial. A Colonel Farquar became his chief staff officer. Others chosen for his staff included Major Baron von Seckendorff, a German of giant size to whom Gustav Klootz was batman, Major Herlth, an Austrian, and Captain Matyuza a Croat. Lieutenant Brody, an ex-regimental sergeant-major of the R.H.A., had charge of the artillery, consisting of ten mountain, four Krupp and six Nordenfelt guns. As London was eager to have early reports of the destruction of that bad man the Mahdi, three journalists were allowed to accompany the expedition. Mr. Power represented *The Times*, but fell ill in Khartoum and could not go on: he was fated, alas, to be murdered in 1885 with Colonel Stewart at Metemmah. Mr. Donovan was the correspondent of the *Daily News* and an artist called Vizetelly was to produce sketches for the *Graphic*. Everything was laid on.

Although the British commander and his staff were easy to find, it was not so with the troops. Only the disgruntled, ill-trained Egyptians of Arabi Pasha were available. The only merit they had was that they were strangers to the Sudan and therefore unlikely to be suborned by the Mahdi. But none of them wished to win laurels on any battlefield, let alone in the Sudan with its terrible name for military disasters. But they were conscripts and had to go. Most of them wept and many were kept in chains until they got well on the way to Khartoum. Their Egyptian commander was Ala ed Wir, who disliked having a British commander and a European staff thrust on top of him and so did most of his Egyptian officers.

Hicks Pasha was under no illusions about the quality of his army but was somewhat reassured by a successful expedition to Sennar in the spring where he routed a Mahdist force and pacified the province. El Obeid, however, had fallen in January, 1883, and the Mahdi was gaining adherents every day. It was imperative to act. So all through the summer, preparations for an expedition to El Obeid were pushed on. On 8th September, there was a big parade in Khartoum to practise the advance in a hollow square. First went two guides followed by scouts. Then came the commander and his staff, then an Egyptian battalion in column, then the guns flanked on each side by Egyptian infantry. The square was closed by another Egyptian battalion in column with cavalry behind them, followed by 5,000 baggage camels. Irregular Arab cavalry brought up the rear. It must have been a dusty disconcerting spectacle. Dissension and intrigue were rampant from the very beginning. There were bitter disputes about the wisdom of advancing to meet the Mahdi, about the best road to follow and about establishing posts on the line of communications which could not be less than 200 miles long from the Nile at Duem, itself 100 miles from Khartoum up the Nile. Nearly all the decisions taken were wrong. The guides were in the pay of the Mahdi : the Sudanese irregulars were treacherous and the camels outside the hollow square were a menace.

But none the less, the advanced party left Duem on 24th September. The hollow square marched by way of the Khor Abu Habl which was a dry water-course to the sourth-east of El Obeid with large pools here and there and pronounced lakes at Shirkeleh, Rahad and El Birket, in that order. There is plenty of vegetation along such Khors in Kordofan—much too much where fanatics with spears are in question. Modern weapons of precision don't help a man very much in thick bush. But the camels could be watered and grazed pleasantly enough and there were 5,000 of them. The army got along all right to begin with, but very slowly, averaging only six miles a day. It found all the Sudanese villages on the way destroyed and deserted : in the dim past, Africa was perhaps the first continent to think of "scorched earth" tactics. On 11th October, the army noticed for the first time that it was being followed by the enemy. Rahad with its considerable lake was reached on 20th October and there was a long halt. It was here that Gustav Klootz decided to desert to the enemy. He had already left his original German master to attach himself to Mr. Donovan : now he left the whole lot. After more disputes about the direction of the advance, the march was resumed along the Khor towards El Birket the third and last lake.

It was at El Birket that the Khalifa had concentrated his main army, finally about 40,000 strong. The news of this soon became known to Hicks Pasha, who then decided to leave the Khor and to move across country to El Obeid, now about twenty miles away to the north-west. It was a terrible march through gum trees about the height and spacing of small apple trees spread over undulating dusty country covered with dry yellow grass, frequent thorn bushes, clumps of bamboo thicket and occasional tibeldi trees. Tibeldi trees have the twisted tortured appearance of very old oaks and give a touch of despair to many a Sudan landscape as they probably did to this one. Their massive stems are often hollowed out to store water for flocks and herds, but none of them held any on the 3rd November for the thirsty soldiers of Hicks Pasha. The heat, the dust, the flies and the lack of water were overpowering. On the 3rd November, about fifteen miles from El Obeid, the Arabs began to close in to kill. Sudanese renegade troops armed with Remingtons fired incessantly at close range into the squares which still hung together and moved doggedly on. That night a zariba of thorns was made as usual and the General even ordered the band to play to enliven the troops, but it soon stopped playing as bullets were flying everywhere. The next day was a Sunday and the moving battle continued. Many guns had to be abandoned as the pack animals were all dead, but others were still firing and Gustav Klootz, now with the Khalifa, noticed that the shells were hitting the branches of trees overhead. Three times the army tried to break the Dervish line but failed. It was now in three large concentrations covering nearly two miles, probably the front and flanking troops of the original hollow square. The 5,000 camels and the irregular cavalry had long before disappeared. The end came on Monday, 5th November, 1883, in the forest of Kashgeil about twelve miles from El Obeid, when the Dervish army fell with its spears on the leading square. Here the British commander and his staff fought with the greatest gallantry to the last. Hicks Pasha fought mounted on his white horse and then on foot, and was one of the last to fall. Baron von Seckendorff was at first mistaken for the General because of his huge size, so his head was sent on a spear to the Mahdi, but Hicks Pasha's head, treated in the same way, soon followed it. Drums and more drums, riders in coats of mail from the Western Sudan, the Khalifa's famous horn made out of an elephant's tusk and a vast concourse of the victorious Dervish army were assembled after the battle on the outskirts of El Obeid to do honour to the Mahdi. He received them smiling benignly mounted on a noble white camel. But his body was now grossly fat and his smile was setting into a mask. His days were numbered, within two years he was dead.

EARTHING OF LOW AND MEDIUM VOLTAGE DISTRIBUTION SYSTEMS IN REGIONS OF HIGH SOIL RESISTIVITY

By MAJOR L. G. T. ROBERTS, R.E.

SUMMARY.

THIS Report describes briefly four of the general methods of protective earthing in use to-day, viz. :—

(*a*) Direct earthing.
(*b*) Continuous earthwire (C.E.W.)
(*c*) Protective multiple earthing (P.M.E.)
(*d*) Earth-leakage circuit-breaker (E.L.C.B.)

The hazards of each method are tabulated from the incidence of faults, the statistics of which were extracted from Electrical Research Association reports available.

The methods of earthing are compared on the basis of efficiency of protection and comparison of each is made, based on costs.

Conclusions are drawn on the economics and degree of safety of the four methods of earthing described and from them it can be seen that the earth-leakage circuit-breaker appears to be the most economical method in most circumstances. In very few circumstances where the soil resistivity is high does either the continuous earthwire or the protective multiple earthing method become more economical than the earth-leakage circuit-breaker.

Appendix "A" gives warning on the use of certain ranges of megger for earth resistance measurement in regions of high soil resistivity.

INTRODUCTION

In many rural districts great difficulty is experienced in obtaining effective earthing of electricity supply systems due to high values of soil resistivity. In the north of Scotland, for instance, the figures range between 30,000 and 500,000 ohm/cm. This Report considers the various methods which have been proposed for earthing low and medium voltage distribution systems in such regions with particular reference to small, isolated distribution systems supplied through a single step-down transformer from a high voltage overhead line.

VOLTAGES DANGEROUS TO LIFE

The sole reason for earthing low voltage distribution systems is to prevent the metal casings of apparatus connected to the system acquiring a voltage to earth which may be a danger to life. Before comparing various methods of achieving this aim, it is essential to establish the voltages that must be considered to be dangerous.

A figure of 40 volts is quoted in the I.E.E. Regulations for the Electrical Equipment of Buildings, in their Regulation 1006, and is generally accepted as the upper limit of safe voltage.

Methods of Earthing

Direct earthing.—The simplest form of earthing of a consumer's installation is that in which all framework of appliances and metalwork, not normally intended to be alive, are connected by an earth continuity conductor to an earth electrode installed by the consumer on his premises.

It is essential that the resistance of the earth electrode shall be low enough either to permit the flow of sufficient current to blow the circuit fuse should an appliance fault occur or to limit the voltage of the earthed metal work to a safe value. Fuses are generally designed to blow within one minute should the fault current exceed about twice their rated current. With fault currents less than twice the rated fusing current, the clearance time will be indefinite, and the voltage drop in the earth continuity conductor and electrode should not therefore exceed 40 volts.

Where electric cookers are installed, the fuses in the control units are generally rated at not less than 30 amp. Thus, in order to limit the fault voltage to 40 volts, at no load, the resistance of the consumer's earth continuity conductor and electrode would have to be not greater than 0.67 ohm. The cost to the consumer of providing an earth electrode of resistance less than one ohm is prohibitive unless an extensive system of buried cables or metal pipes already exists in the neighbourhood and, in fact, the earth electrodes provided by the consumer commonly have a resistance of several hundred ohm. This state of affairs has led supply authorities to consider alternative methods of earthing.

Continuous earth wire.—One method of ensuring that dangerous voltages do not arise in electrical apparatus is to provide a continuous metallic connexion between all earthed metal work and the neutral point of the supply transformer. This connexion may be a separate earth wire on the overhead line, earthed at the supply transformer and preferably connected in addition to an earth electrode on each consumer's premises.

The total voltage drop in a consumer's earth continuity conductor and the line earth wire when a sustained fault current flows, should not exceed 40 volts. This means that, with the largest circuit fuse rated at 30 amp. their total resistance should not exceed 0.67 ohm. Assuming the resistance of the earth continuity conductor does not exceed 0.5 ohm and the line earth wire is 0.0225 sq. in. copper section, the length of the line earth wire should obviously be limited to a few hundred yards.

The value of the earth resistance at the transformer is only important in relation to (*a*) faults to extraneous metal-work not connected to the earth wire and (*b*) affording protection against an inter-winding fault in the transformer.

The value of the earth resistance to safeguard the L.V. system against an inter-winding fault in the transformer needs careful consideration. No fixed upper limit can be laid down as this will vary with the capacity of the transformer. However, if an upper limit of transformer capacity can be assumed, a maximum safe value of earth resistance may be derived. In rural areas, the maximum capacity of a transformer or group of transformers fed through a single H.V. fuse from an 11-kV. system will probably not exceed 300 kVA. The largest size of H.V. fuse will therefore be 15 amp. The value of earth resistance must therefore be such that a 15-amp H.V. fuse will blow in some minute fraction of a second (to all intents and purposes instantaneously) on the occurrence of an inter-winding fault.

Reference has been made to current/time graphs for pole-mounted fuses and it has been found that a H.V. 15-amp H.R.C. cartridge fuse will blow in 0.08 sec., with 68 amp flowing. Relating this to an 11-kV. transformer, the upper limit of resistance to earth is therefore,

$\frac{11000}{\sqrt{3} \times 68} = 100$ ohm approximately. If a 15-amp fuse protects a 3.3-kV. transformer the resistance to earth must be proportionately lower, i.e. $\frac{3300}{\sqrt{3} \times 68} = 30$ ohm approximately.

It is therefore recommended that these figures of 100 ohm and 30 ohm for 11 kV. and 3.3 kV. transformers respectively be adopted as the maximum resistance to earth of the transformer L.V. neutral on a system using a continuous earth wire. It is also considered desirable to standardize at a maximum resistance to earth of 100 ohm for transformers having higher voltage windings (22 kV. or 33 kV.) as, at higher values of earth resistance, the insulation of the system may be unnecessarily impaired.

Protective multiple earthing.—The cost of a continuous earth wire on the overhead line may be saved by connecting each consumer's earth continuity conductor directly to the neutral conductor of the supply at the point where it enters the consumer's premises. If the neutral conductor is then earthed at a number of points, the system is known as protective multiple earthing.

Conditions have been specified for this form of earthing by the Ministry of Fuel and Power which state that the resistance of a consumer's earth continuity conductor shall not exceed 0.5 ohm; the cross-sectional area of the neutral conductor shall not be less than that of the phase conductors ; and the neutral conductor shall be earthed near the supply transformer, at the remote end of each distributing main, or branch of a distributing main, and at such additional points, as equally spaced as possible, necessary to give an over-all resistance to earth not exceeding 10 ohm.

Since the cross-section of the phase conductors will be such as to keep the voltage drop within the statutory limits under normal load conditions, it is unlikely that the voltage drop in the neutral and earth continuity conductors due to a fault current will exceed 40 volts if the above conditions are satisfied.

Earth-leakage circuit-breaker.—All the preceding methods rely on the presence of a low-resistance fault current path to limit the voltage rise of earthed metal casings to a safe value. An alternative method is to use a relay to detect dangerous voltages and isolate the faulty equipment from the supply. This is the principle on which the voltage operated earth-leakage circuit-breaker operates.

An automatic circuit-breaker whose trip coil is connected in series with the earth electrode on the premises is installed at the point of supply to each consumer's installation. B.S. 842 specifies that a voltage operated earth-leakage circuit-breaker shall open instantaneously when 40 volts is suddenly applied to the trip coil in series with a resistance of 500 ohm. Thus, no hazard will arise on the installation provided the resistance of the earth electrode does not exceed 500 ohm and the circuit-breaker is maintained in a sound operating condition. An additional advantage of this method of earthing is that the fire risk is reduced due to the small magnitude and short duration of the fault current.

The alternative method of employing the earth-leakage circuit-breaker is to connect the earth continuity conductor to the neutral conductor of the supply and earth both through the trip coil of the circuit-breaker. Appliance faults are then cleared by the blowing of the circuit fuse, as with protective multiple earthing, and the earth-leakage circuit-breaker is only called upon to operate should a break occur in the neutral conductor. Should, however, a break in the neutral occur co-incident with failure of the circuit-breaker to trip, the consumer's appliance frameworks would obtain a dangerous voltage to earth. Current regulations of the Ministry of Fuel and Power do not permit this method of earthing.

System Defects

Appliance faults.—Dangerous conditions most commonly arise due to earth faults on consumers' apparatus. These may be divided into two main types. The first occurs when abrasion of the insulation or displacement of a conductor brings live metal into contact with an earthed metal casing and the fault resistance has a value of only a few ohm. The second type of fault is produced by deterioration of the insulation or tracking across its surface due to deposits of dirt and damp, and may have a resistance of several thousand ohm. Low resistance faults are generally considered to be far more prevalent than high resistance faults.

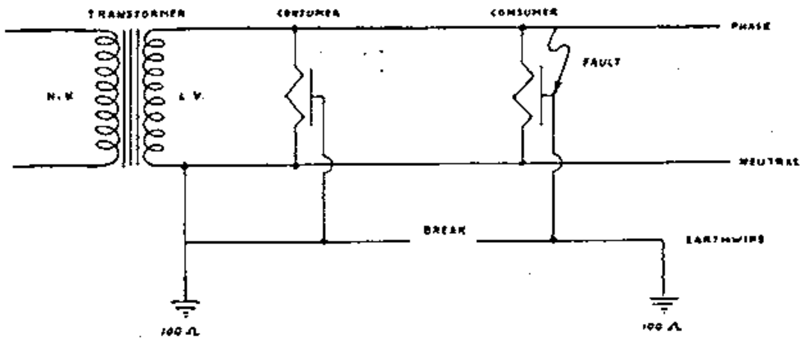
If an appliance that is unearthed develops a fault to which the full phase voltage of 240 volts is applied, a fault resistance of 20,000 ohm will be required to limit the current flowing through the body of a person, whose resistance to earth is unlikely to be below 4,000 ohm, to a safe value. Thus any appliance with an insulation resistance of less than 20,000 ohm should be considered faulty.

Broken earth continuity conductor.—A break in an earth continuity conductor will leave the consumer's apparatus wholly or partly unearthed whatever the method of earthing adopted. Whether or not a faulty appliance is potentially dangerous will then depend only on the fault resistance and voltage at the point in the circuit where the break occurs. Maintenance of the earth continuity conductor in a sound condition is the responsibility of the consumer, and since the risk due to a broken earth conductor applies equally to all methods of earthing it need not be considered when comparing alternative methods. However, it probably constitutes one of the main hazards on any installation, and safety would be greatly improved if the earth continuity conductor were subjected to continuity tests at regular intervals, although, of course, these cannot be enforced.

Broken continuous earth wire.—Should the continuous earth wire be open circuited at some point and should an appliance fault occur on the side of the break remote from the supply, the voltages to which metal-work connected to the earth wire on either side of the break will be raised will depend on the ratio of the resistances of the earth electrodes on either side of the break to the total impedance of the fault current path.

For example, suppose a transformer supplied a single distributor, the earth wire of which has an over-all resistance to earth of 50 ohm. Assume a break occurs in the earth wire at such a position that the resistances of the earth electrodes on either side of the break are 100 ohm (see Fig. 1), and the total earth resistance in the fault current path 200 ohm. Thus even a 1-amp fuse is unlikely to blow should an appliance fault occur on the side of the break remote from the supply, and with a fault resistance less than 400 ohm, the voltage of the earthed metal on both sides of the break will exceed 40 volts. Since the resistances of the majority of appliance faults probably lie within the range 0–400 ohm, any fault which occurs on the remote side of the break in the line earth wire must thus be considered potentially dangerous to all consumers connected to the system.

FIG 1.
CEW



Note.—The values of resistance to earth of the electrodes used in the above example were chosen for ease of calculation but are representative of values that might be expected in practice.

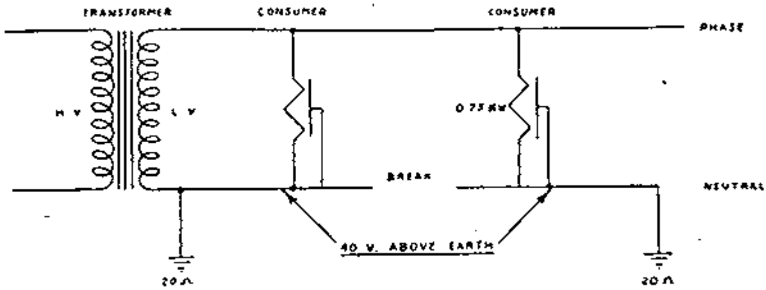
However, should a break occur in a service earth wire connected to a single consumer and an appliance fault occur on that consumer's premises, since the resistance of the consumer's earth electrode will probably be several hundred ohm, the fault current returning through earth to the neutral of the supply transformer is unlikely to be large enough to raise the voltage of the earth wire on the transformer side of the break to a dangerous value. Thus a break in a service earth wire will normally affect only one consumer.

Broken neutral conductor.—A broken neutral conductor does not affect the safety of a system protected by direct earthing or by a continuous earth wire. On a system with protective multiple earthing, however, if there is any load connected beyond the break, the load current will be diverted through the earth electrodes and produce a voltage difference between the neutral conductor and earth on both sides of the break.

A consumer with an electric cooker or other heating load switched on may have a load resistance as low as 20 ohm (3 kW. at 240 volts). Thus in order to ensure safety when a service neutral conductor breaks, an earth electrode with a resistance not exceeding 4 ohm would have to be installed on each consumer's premises. The cost of this is prohibitive where the soil resistivity is high and, as previously mentioned, the consumer's earth electrode often has a resistance of several hundred ohm, consequently all metal work connected to the neutral conductor may assume a voltage approaching line to earth voltage on the occurrence of a break in the service neutral conductor.

The effect of a break in the neutral conductor of a single phase line will depend on the resistance of the earth electrodes on both sides

FIG 2
PME



of the break and the load being taken on the remote side at the time of the break. Consider the case of a system consisting of a single distributor earthed by line electrodes situated near the transformer and near the far end of the line, with an over-all resistance to earth of 10 ohm as permitted by the Ministry of Fuel and Power. If a break occurs in the neutral conductor near the centre of the line so that the resistance of the earth electrodes on either side of the break is 20 ohm (see Fig. 2), then the voltage difference between the neutral conductor and earth will exceed 40 volts on both sides of the break if the connected load on the remote side of the break is greater than 750 watts.

Thus connexion of the metal casings of apparatus to the neutral conductor of a single-phase line while reducing the danger due to appliance faults introduces an additional hazard due to the breaking of the neutral conductor.

On a three-phase system, the displacement of the neutral point, due to a break in the neutral conductor, will depend on the degree of unbalance in the load on the remote side of the break. If it is assumed that unbalance is caused by variation of the load on one phase only, then the load on this phase may range between 57 and 160 per cent of the load on the other two phases without producing more than 40 volts difference between the neutral conductors on opposite sides of the break. It is thus evident that a break in the neutral conductor alone of a three-phase line is unlikely to give rise to dangerous conditions on a system employing protective multiple earthing unless it occurs near the end of the line and involves only one or two consumers.

Broken phase conductor.—By stringing the neutral conductor or earth wire on an overhead line between the phase conductors and ground, it is possible to ensure that the majority of phase conductor breakages produce short circuit currents which blow the L.V. fuses at the supply transformer or the H.V. fuses if no L.V. fuses exist.

However, should a phase conductor break without contacting a sound phase or the neutral conductor or earth wire, the fault current due to a length of conductor lying on the ground will probably be insufficient to blow either the L.V. fuses or the H.V. fuses. The current flowing through the earth electrodes to the transformer neutral will then produce a voltage difference between any metalwork connected to the neutral conductor or earth wire and earth, but in regions of high soil resistivity this is unlikely to attain a dangerous value. For example, if the over-all resistance of the earth electrodes connected to the transformer neutral is 10 ohm, the broken conductor would have to have a resistance to earth of less than 50 ohm to raise the neutral voltage by 40 volts. In soil of resistivity, 100,000 ohm-cm. a length of about fifty yards of conductor, even burried two feet in the ground, which, of course, could not occur, would be required to obtain this value of resistance.

In order to reduce the danger to people or animals who may approach the broken conductor, however, it is essential that it should be speedily isolated.

Should the neutral conductor and one phase conductor of a three-phase line be severed without disconnecting the two sound phases, the neutral conductor on the remote side of the break will assume a voltage which may approach 120 volts on a 415/240-volt system. Also, if only one phase conductor is left connected, conditions will be similar to those for a single phase supply with a broken neutral conductor. The simultaneous disconnexion of the neutral conductor and one or two phase conductors of a three-phase line may thus constitute as great a hazard to a system with protective multiple earthing as does the breakage of the neutral conductor only of a single-phase line.

Earth-leakage circuit-breaker defects.—Failure of voltage operated earth-leakage circuit-breakers to operate may be attributed to three main causes, namely :—mechanical defects, open circuited trip coils, short circuited trip coils. In the past, the majority of failures have been attributed to mechanical defects, probably mainly sticking of the mechanism in the closed position. In order to obtain the required sensitivity without unduly increasing the size of the circuit-breaker, the trip coils have to be wound with fine wire ; they are therefore liable to be burnt out by excessive fault currents such as produced by flashover due to lightning discharges. Open circuited trip coils may also be caused by corrosion if the circuit-breaker is mounted in a damp situation, or by mechanical breakage. Short-circuiting or shunting-out of the trip coils may be caused by inadvertent contact between metal work connected to the earth continuity conductor and metal-work directly earthed, or by placing the earth electrode of the E.L.C.B. in the resistance area of a water main or other low resistance to earth electrodes to which the apparatus is connected.

If each consumer's installation is earthed individually through an earth electrode of resistance not greater than 500 ohm, it is evident that the great majority of appliance faults will produce dangerous voltages on earthed metal should the circuit-breaker fail to operate due to any of the above causes.

Incidence and Duration of Faults

Before comparing the relative safeties of installations with various methods of earthing, it is necessary to consider the incidence and duration of the faults which may occur. The Electrical Research Association has collected some information on the subject and has published it in their Technical Report Reference V/T 106 entitled "The Cost and Efficiency of Protective Earthing of Low and Medium Voltage Systems by Various Methods."

To assume that ten out of every thousand appliances develop faults each year appears to be reasonable from the figures given in this Report. Appliances developing faults while the earthing system is in a sound condition will generally be immediately isolated either by the blowing of a fuse or by operation of an earth-leakage circuit-breaker but, as has been shown in the foregoing discussion, the majority of appliance faults are likely to be potentially dangerous if the earthing system is defective, and will persist until detected by generation of heat at the point of fault or by a person receiving an electric shock.

The Electrical Research Association suggest 20 in 1,000 per annum as a reasonable figure for the number of installations developing open circuits on their earth continuity conductors. Continuity tests on the earth conductors are not usually performed at regular intervals on domestic installations, and thus open-circuits will generally remain until a person receives a shock on the occurrence of an appliance fault, and may not be corrected even then. Thus, after the passage of a number of years, an appreciable fraction of the total number of earth continuity conductors on the system is likely to be in a defective condition.

For service wires (phase, neutral or earth) a figure of 1 in 1,000 breakages per annum is suggested. A break in the phase or neutral conductor will interrupt the supply and will therefore generally be remedied within a few hours. A break in the earth wire, however, is liable to remain undetected for an indefinite period since staff is usually not available for regular inspections of the lines, and in any case visual examination will not disclose breaks in the form of high resistance joints.

Statistics for an actual system published in the Report indicate that about two cases of the line earth wire breaking occur per annum per thousand miles of overhead line. Also about two cases per annum of the breaking of the neutral conductor only of a single-phase line, or of the neutral conductor and one or two phase conductors of a three-phase line, may reasonably be assumed per 1,000 miles of overhead line.

The number of earth-leakage circuit-breakers developing defects each year was taken by the Electrical Research Association to be 50 in 1,000. This figure includes mechanical defects and open-circuits of the trip coil. The performance of up-to-date circuit-breakers may be somewhat better than suggested by the figure, but it is obviously advisable to test them at regular intervals to prevent an accumulation of defective circuit-breakers connected to the system. This may be simply done by means of a push-button which is provided on the earth-leakage circuit-breaker to connect the trip coil through a current limiting resistor to the phase conductor of the supply. Assuming that tests are performed once a year, although experience may prove less frequent inspection to be adequate, then the average duration of an earth-leakage circuit-breaker fault will be six months.

Risk of Electric Shock

Assuming that on the average each consumer has three appliances connected to the supply, it can be inferred from the figures given above that faults will probably arise on thirty out of every 1,000 consumer's installations each year. If the installations are completely unearthed, each fault is likely to result in a person receiving an electric shock.

With directly earthed installations, appliance faults are dangerous only if they occur when the earth continuity conductor is broken. If, for example, it can be assumed that not more than one quarter of the earth continuity conductors are defective at any time, the number of incidents occurring should be reduced to about 7.5 per 1,000 consumers per annum.

For lengths of line met with in practice, the risk of a broken earth wire would appear to be small compared with the risk of a broken earth continuity conductor. Thus the safety of a system with a continuous earth wire should approach that of a directly earthed system.

Similarly the risk introduced by broken neutral conductors on systems with protective multiple earthing is small. Assuming that each system consists of a single line of average length one mile, and that one quarter of the earth continuity conductors are defective, and allowing for the fact that installations with open-circuited earth continuity conductors are not endangered by breaks in the neutral conductor it would appear that dangerous conditions will probably arise on about ten out of every 1,000 consumer's installations per annum.

Where installations are individually earthed through earth-leakage circuit-breakers that are tested annually, the number of defective circuit-breakers connected to the system should never exceed about one-tenth the number of broken earth continuity conductors ; therefore danger of electric shock should arise on only about eight in every 1,000 installations per annum.

If the neutral conductor is multiple earthed through earth-leakage circuit-breakers, the risk of electric shock will lie between that for a directly earthed system and that for a system with conventional protective multiple earthing.

Another point to be remembered is that many earth continuity conductor defects are due to high resistance joints which, while sufficient to prevent the blowing of fuses, will not necessarily prevent the operation of earth-leakage circuit-breakers. Thus the figure taken for the number of earth continuity conductor breakages occurring per annum might well be reduced when earth-leakage circuit-breakers are considered.

Under the conditions described above, there would appear to be little difference between the safeties of systems with direct earthing, protective multiple earthing, continuous earth wire, or earth-leakage circuit-breakers. Choice of method of earthing for any particular system may therefore be freely based on a comparison of costs for the various alternatives.

Types of Earth Electrode

Consumer's earth electrodes.—The earth electrode on each consumer's premises may take the form of an earth rod or tube. It generally has a resistance of several hundred ohm and the cost of installation is, of course, borne by the consumer.

Present-day practice favours the use of tubes rather than rods. The difference in ohmic resistance to earth, diameter for diameter, is, of course, nil ; however, under certain conditions of hard, stony soil, the solid rod may well drive to greater depths, without undue bending, than the tube.

Using Wehner's formula for these as earth electrodes :—

$$R = \frac{\rho}{83l} \log_{10} \frac{48l}{d}$$

where R = Resistance in ohm.

ρ = Soil resistivity in ohm/cm.

l = Length of electrode in feet.

d = Diameter of electrode in inches.

FIG. 3

COPPER WIRE 0·058 SQ. IN. BURIED 2 FT. IN GROUND
LAID IN A SINGLE STRAIGHT LENGTH

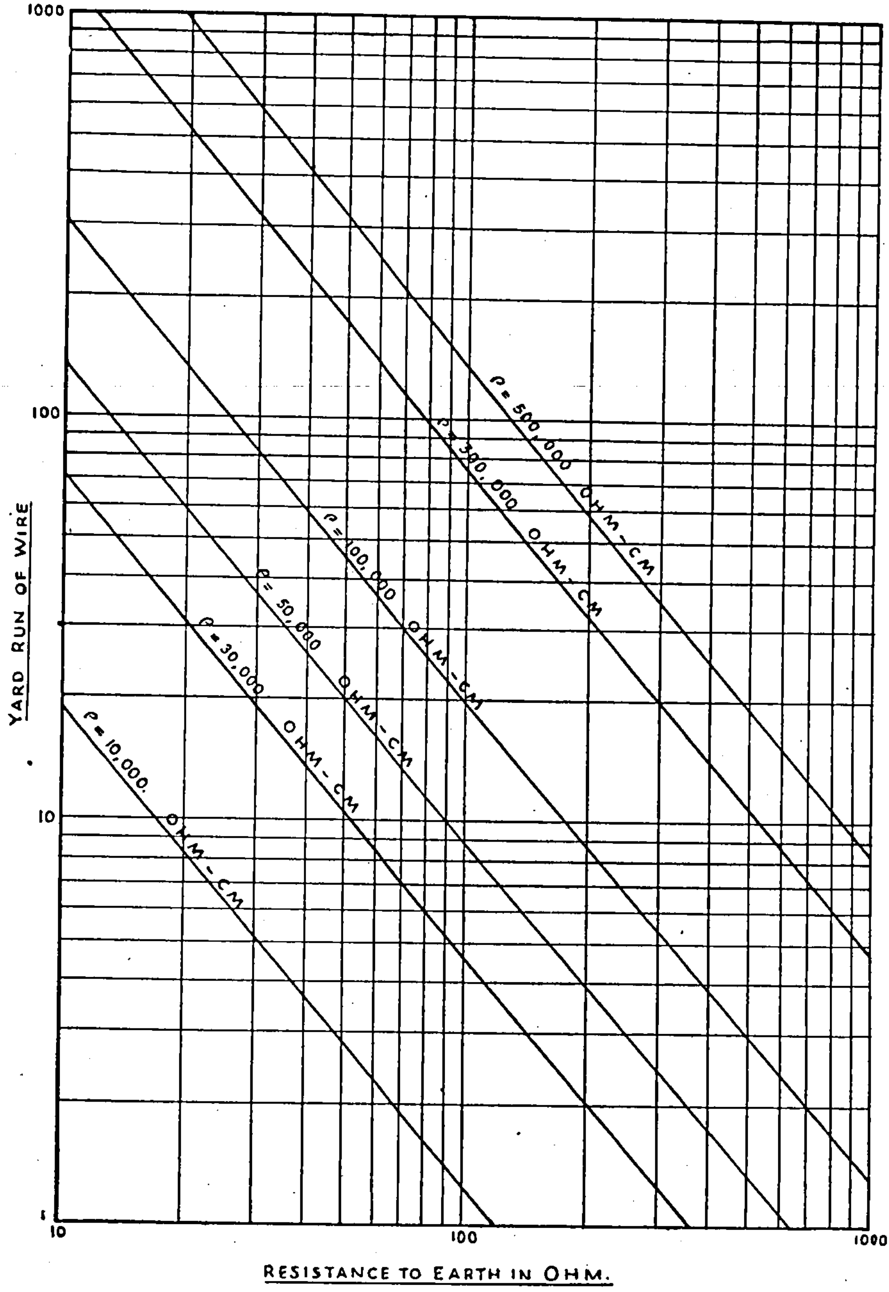
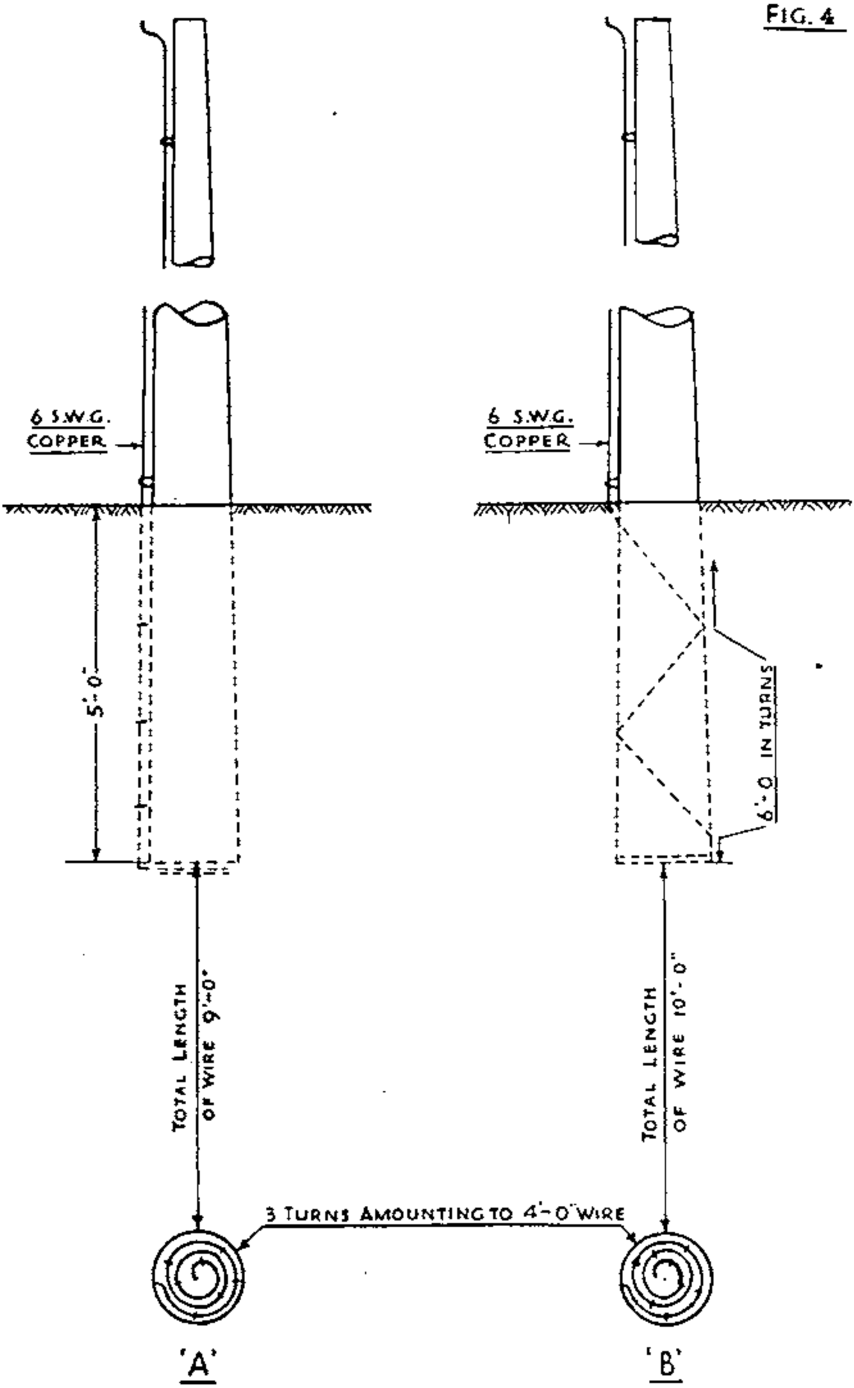


FIG. 4



BUTT EARTHS

Transformer earth electrodes.—These are usually lengths of copper wire or strip buried in the soil, or rods or tubes where these can be driven. Wehner's formulae for copper wire and strip used as earth electrodes are:—

Copper wire

$$R = \frac{\rho}{250L} \log_{10} \frac{108L}{t \times d}$$

Copper strip

$$R = \frac{\rho}{250L} \log_{10} \frac{216L}{t \times w}$$

where R = Resistance in ohm.
ρ = Soil resistivity in ohm/cm.
L = Length of electrode in yards.
t = Depth of burial in feet.
d = Diameter of electrode in inches.
w = Width of strip in inches.

These formulae tend to give a lower resistance to earth value in very high soil resistivity areas (500,000 ohm/cm and above) than is found in actual practice.

The usual length of wire is 50 ft., buried to a depth not greater than two feet. However, it may be necessary to use varying lengths of conductor and the graph at Fig. 3 gives the resistance to earth for any length and for a number of resistivity values at a standard depth of 2 ft. Ohmic resistance values for any value of soil resistivity may be found by interpolation on the log graph paper.

Line earth electrodes.—Where multiple earthing of the neutral conductor is permitted on an overhead line system, the line earth electrodes may be rods or tubes, or lengths of copper wire buried in the ground. Rock or stony soil make the driving of rods or tubes impossible in many areas. A form of earthing widely adopted in the north of Scotland for lines on systems with protective multiple earthing has therefore been a flat, spiral coil of copper fixed to the base of each pole butt. This is generally known as a butt earth.

If this is installed at the time the line is erected, the cost is only that of providing the copper conductor and securing it to the pole.

A number of tests were carried out to determine the resistance to earth of butt earth electrodes in the north of Scotland. Two types of testing gear were used :—

(i) the earth-testing megger 0–3,000 ohm.

(ii) the fall of potential method using recording ammeters and voltmeters.

The types of butt earth employed were as shown at Fig. 4 ; the earth electrodes being sited in soils having a resistivity range 30,000 to 500,000 ohm/cm.

From results plotted it was seen that the slight increase in length of copper wire gained by winding the electrode round the five or six feet of the pole in the soil had little effect on decreasing the ohmic resistance. It was found from the tests that the resistance to earth of this type of electrode was $R = \frac{4\rho}{1000}$ ohm, where p is the resistivity in ohm/cm. The resistance to earth varied in direct proportion to the resistivity.

P.M.E. installations using entirely this type of earth electrode may have a butt earth at the base of every pole. Therefore, the butt earth method of earthing is limited by the number of poles in the L.V. network. In the north of Scotland a large network would be of the order of forty poles. Since the total resistance to earth of the L.V. neutral must not at any point exceed 10 ohm, the average value per butt earth cannot, therefore, exceed 400 ohm on a forty-pole network. This shows that for P.M.E. installations of approximately forty poles (making use of butt earths only) the maximum value of soil resistivity that is acceptable is 100,000 ohm/cm.

In cases where the combination of the number of butt earth electrodes and the soil resistivity gives a total value to earth in excess of the 10 ohm laid down by the Ministry of Fuel and Power, additional electrodes may be connected to the system in the form of buried copper conductor or strip laid in lengths in the ground, or earth rods or tubes sited along the pole routes as required.

Where this is necessary, care must be taken to see that the copper wire, strip, rod or tube is placed outside the resistance area of the butt earth, in order that full benefit is obtained from the additional earth electrodes.

Comparison of Costs of Various Methods of Earthing

(Based on material and labour costs for a large undertaking in the United Kingdom in 1951 and used below for comparing the relative costs of various methods of earthing.)

Direct earthing.—The cost of direct earthing is prohibitive in regions where the soil resistivity exceeds 5,000 ohm/cm. unless an extensive system of buried metallic pipes or cable sheaths exists on or near the consumer's premises. Since this is rarely the case in rural areas, the cost of direct earthing cannot be considered.

The cost of a transformer earth electrode.—(Using 50-ft. lengths of 0.058 sq. in. copper wire buried 2 ft. deep in average soil.)
Supplied and erected, 17s. + 1s. per f.r. of wire in soil = £3·35.

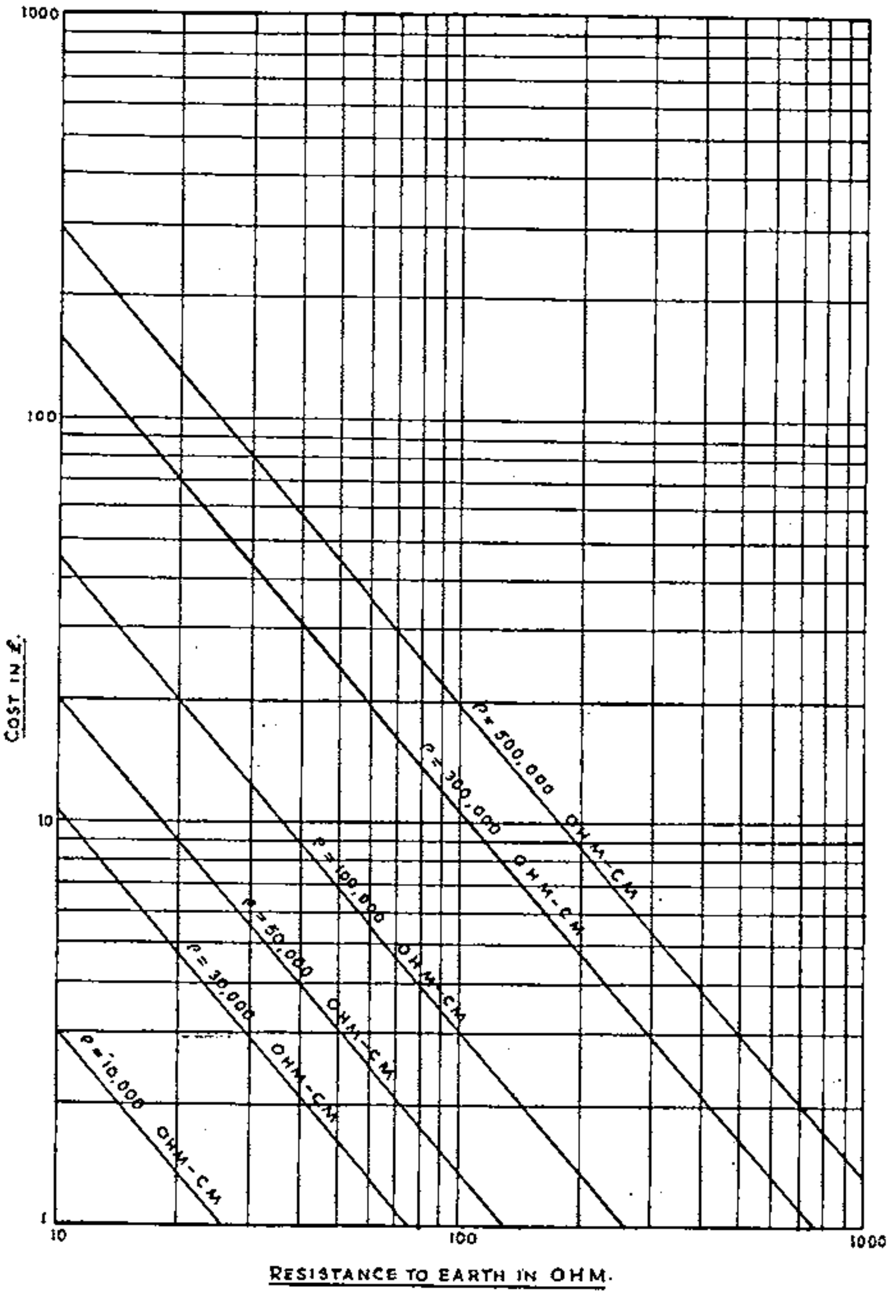
Its resistance to earth will be approximately $\frac{1.2\rho}{1000}$ where ρ is the resistivity in ohm/cm. Therefore the cost of obtaining a resistance to earth of R ohm will be :—

$$£3{\cdot}35 \times \frac{1.2\rho}{1000R} = £\left(\frac{4\rho}{1000R}\right)$$

(Based on a resistivity of 10^5 ohm/cm.)

FIG. 5

STANDARD EARTH ELECTRODES. COPPER WIRE 0·058 SQ. IN. BURIED 2 FT. IN GROUND, LAID IN A SINGLE STRAIGHT LENGTH



The cost of a consumer's earth electrode.—(Using tubes 6 ft. long, 1 in. diameter, driven in average soil.)

Supplied and erected, £1.5 per tube forming the earth electrode.

Its resistance to earth will be, $\frac{5.25\rho}{1000}$

Therefore the cost of obtaining a resistance to earth of R ohm will be

$$£1.5 \times \frac{5.25\rho}{1000R} = £\left(\frac{8\rho}{1000R}\right)$$

The cost of a line electrode (using butt earths only).—Supplied and erected, £0.65 per butt earth.

The cost of a P.M.E. system (using butt earths only).

(*a*) Cost of transformer earth (100 ohm) using 6 ft., 1 in. diameter tubes, $£\left(\frac{8\rho}{10^5}\right)$

(*b*) Cost of butt earths (assuming forty poles per mile of line).

Cost is therefore :—

$£\left(\frac{8\rho}{10^5} + 0.65E_L\right)$ where E_L is the number of butt earth electrodes.

Therefore the total cost per mile of line will be :—

$£\left(\frac{8\rho}{10^5} + 26L\right)$ where L is the length of the line in miles.

If the number of butt earths is insufficient to produce a resistance to earth of 10 ohm, additional earth electrodes (0.058 sq. in. copper wire laid 2 ft. in soil) will be required. The total cost therefore increases to approximately :—

$$£\left[\frac{8\rho}{10^5} + \frac{5.2\rho}{10^3}\left(\frac{1}{10} - \frac{10^4 \times L}{\rho}\right) + 26L\right]$$

The quantity $\frac{5.2\rho}{10^3}$ is an approximation ; the cost/resistivity follows a logarithmic law (see Fig. 5).

The cost of a continuous earth wire system.

(*a*) Cost of transformer earth (100 ohm) using 6 ft., 1 in. diameter tubes, $£\left(\frac{8\rho}{10^5}\right)$

(*b*) Cost of main line earth wire 0.0225 sq. in. including insulators and fittings, supplied and erected, £200 per mile.

(*c*) Consumer's service earth wire, allowing a 20-yd. service and 7 yds. of lead-in, £5.

The above can be put into the general form :—

$$£\left(\frac{8\rho}{10^5} + 200L + 5n\right)$$

where L = Length of the line in miles.
ρ = Soil resistivity in ohm/cm.
n = Number of consumers on network.

The cost of an earth-leakage circuit-breaker system of earthing.—

(*a*) Cost of transformer earth (100 ohm) using 6 ft., 1 in. diameter tubes, £$\left(\frac{8\rho}{10^5}\right)$

(*b*) Supply and erect E.L.C.B. (30 amp) on consumer's premises and provide 500 ohm earth electrode.

Supply and erection of E.L.C.B., £2.5.

Supply and erection of 500 ohm earth electrode :—

£$\left(\frac{1.5\rho}{10^5}\right)$ using 6 ft., 1 in. diameter tubes.

The above can be put into the general form :—

$$£\left[\frac{8\rho}{10^5} + \left(\frac{1.5\rho}{10^5} + 2.5\right)n\right]$$

where n = number of consumers.

Conditions on which an economic choice depends.—The cost of earthing depends on three main variables ; the length of the overhead line or network, the number of consumers and the soil resistivity. Briefly, therefore, it may be seen that with the present-day cost of copper, any method of earthing involving large quantities of copper wire, whether it be used above or below the ground, is bound to be expensive. Both the continuous earth wire and the protective multiple earthing methods under many circumstances in rural areas require large quantities ; the former above ground and the latter laid in the ground. On the other hand, the earth-leakage circuit-breaker method of earthing is not affected by the length of an overhead line, nor does it utilize multiple earthing and consequently its cost is much lower than the other two methods, except when the number of consumers is very large.

Conclusions

The value of the resistance to earth of a consumer's earth electrode must be less than one ohm if frameworks of appliances are to remain at 40 volts or below on the occurrence of a fault. The cost of obtaining this figure in rural areas with overhead distribution is usually prohibitive.

The length of a continuous earth wire, if of 0.0225 sq. in. copper section, should be limited to a few hundred yards if fault voltages on consumer's frameworks of appliances are to be limited to 40 volts.

Any apparatus with an insulation resistance of less than 20,000 ohm is dangerous.

Breaks and high resistance joints in earth continuity conductors are probably the main causes of electric shocks whatever the method of earthing employed.

A break in the line earth wire of a C.E.W. may endanger the consumers connected to the system on both sides of the break in the earth wire, whereas a break in a service earth wire need not necessarily affect more than the consumer whose service earth wire is broken.

Similarly, on single-phase systems with P.M.E., the voltages produced by diversion of the load current through the earth electrode, due to a break in the neutral conductor may affect the safety of the whole system, if it occurs in a line neutral conductor, but will probably be a hazard to only one consumer if the break occurs in a service neutral.

On three-phase systems with P.M.E., a break in the line neutral conductor alone is unlikely to produce dangerous voltages, but if it coincides with the disconnexion of one or two phase conductors, then conditions are similar to those for a single phase system with a broken neutral conductor.

The fault current that flows when a length of broken phase conductor lies on the ground is unlikely to be sufficient to blow the transformer fuses or to produce a dangerous rise in voltage of the neutral point of the supply transformer.

Methods of earthing that employ a continuous earth wire, protective multiple earthing, or earth-leakage circuit-breakers can all provide a standard of safety for low and medium voltage distribution systems in regions of high soil resistivity little below that generally conceded for directly earthed installations in areas where earths of low resistance exist.

Economic Comparisons of the Various Methods

(*a*) The earth-leakage circuit-breaker is the most economical method of earthing under practically all circumstances of rural distribution (see Fig. 6).

(*b*) For very short lengths of overhead line (100 yards or less) on single transformer, single consumer networks, or a single transformer with a concentrated small group of consumers numbering about five, the continuous earth wire method is competitive in cost with the earth-leakage circuit-breaker (see 6(*e*) of Fig. 6).

(*c*) For lengthy networks and low resistivity values (1 mile of line and 100,000 ohm/cm. or less) protective multiple earthing is competitive in cost with all the other methods and in some circumstances may be the cheapest method of earthing (see 6 (*a*) (*b*) (*c*) and (*d*) of Fig. 6).

(*d*) For very short networks and for values of resistivity over 100,000 ohm/cm., protective multiple earthing costs rise steeply and exceed all the other alternatives (see 6 (*e*) of Fig. 6).

(*e*) For networks of one quarter mile and less and resistivity values of 300,000 ohm/cm. or more protective multiple earthing ceases to be competitive with the other methods even when twenty consumers are connected.

MILE OF LINE (40 POLES)

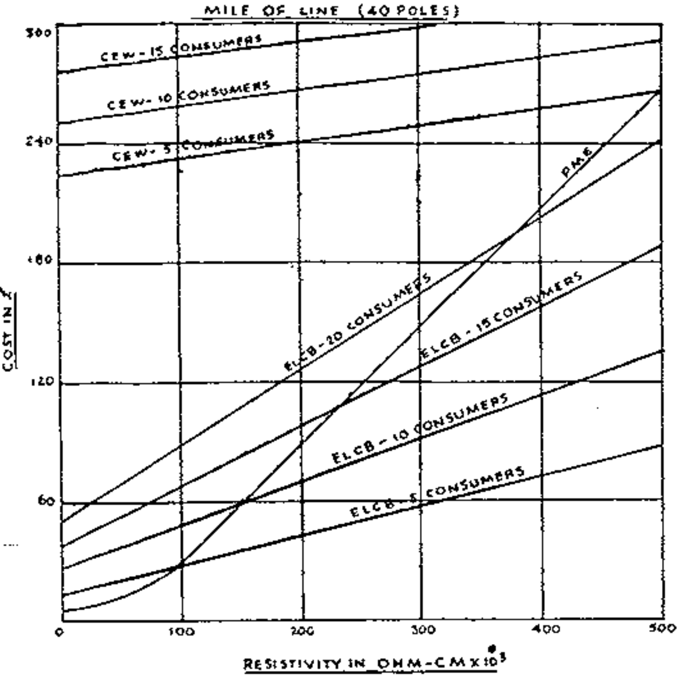


FIG: 6A

1/2 MILE OF LINE (20 POLES)

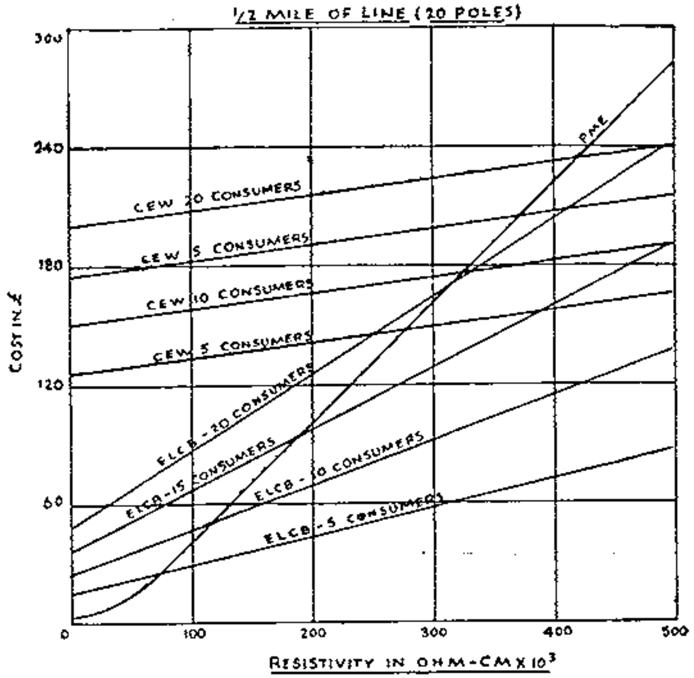


FIG: 6B

1/4 MILE OF LINE (10 POLES)

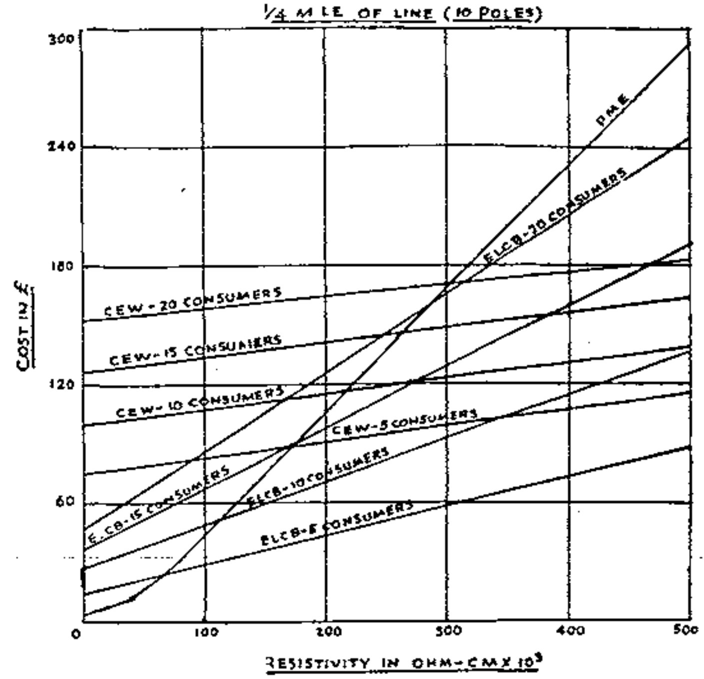


FIG: 6C

1/8 MILE OF LINE (5 POLES)

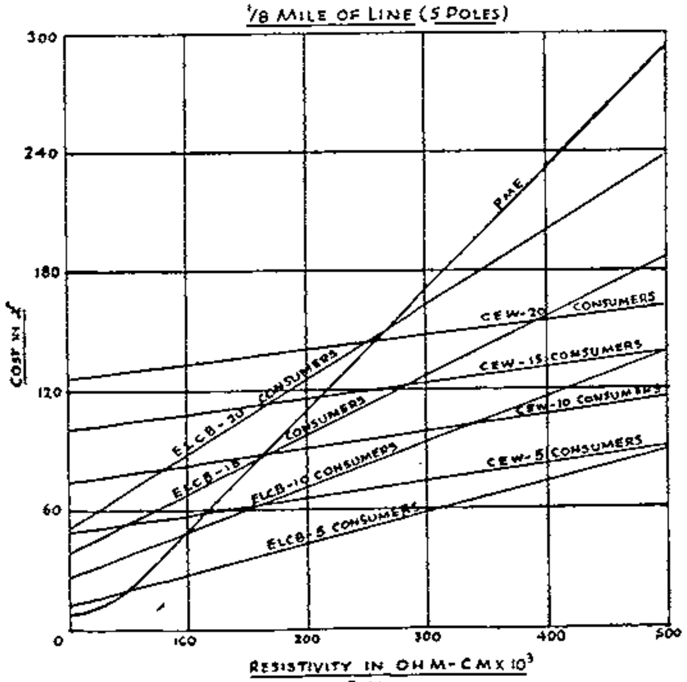


FIG: 6D

100 YARDS OF LINE (2 POLES) ONE CONSUMER
OR CONCENTRATED GROUP OF CONSUMERS UP TO 5 No

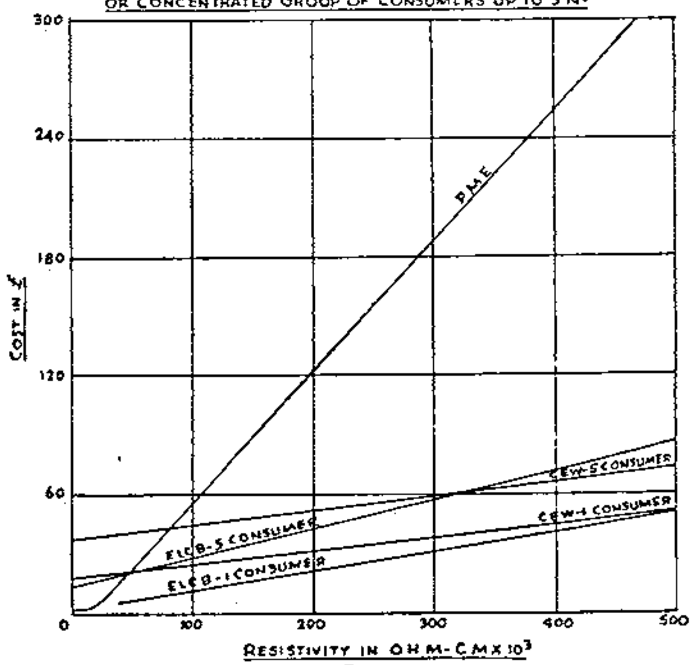


FIG: 6E

Note:—The cost of the PME method of earthing is based on the following:— The number of butt earths required to give the statutory 10 Ohm to earth of the neutral conductor and additional earth electrodes—0·058 sq. in. copper wire laid 2ft. in ground where these are necessary.

COMPARISON OF COST CEW, PME AND ELCB METHODS OF EARTHING

FIG. 6

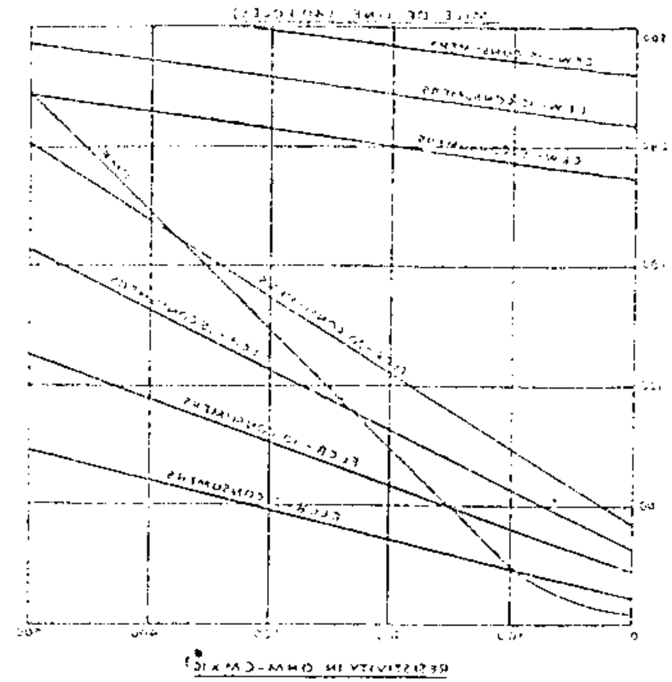


FIG. 6A

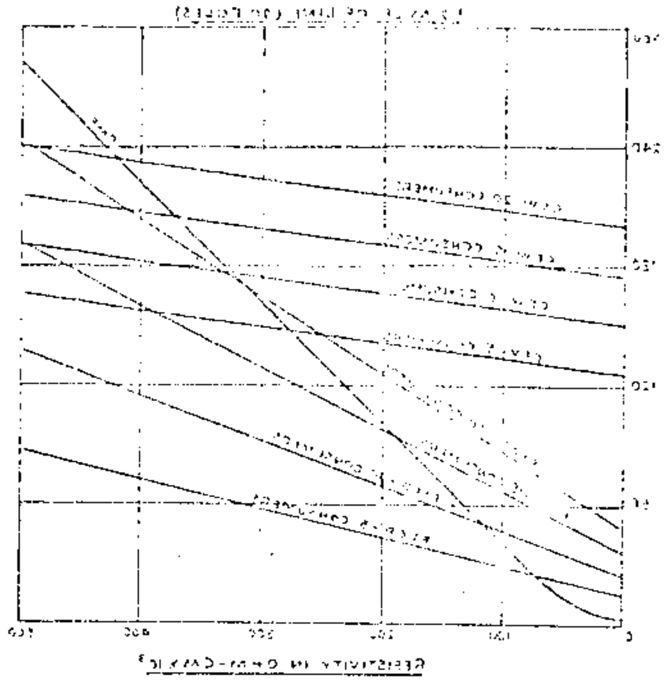


FIG. 6B

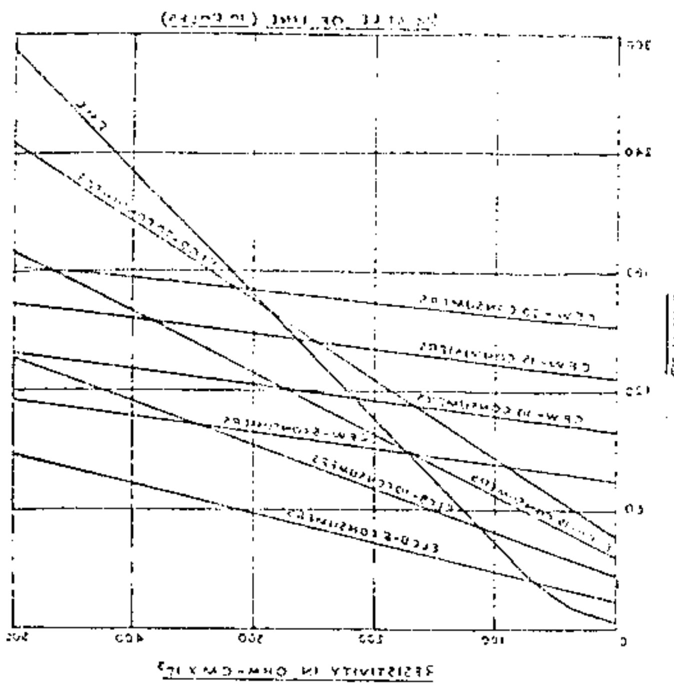


FIG. 6C

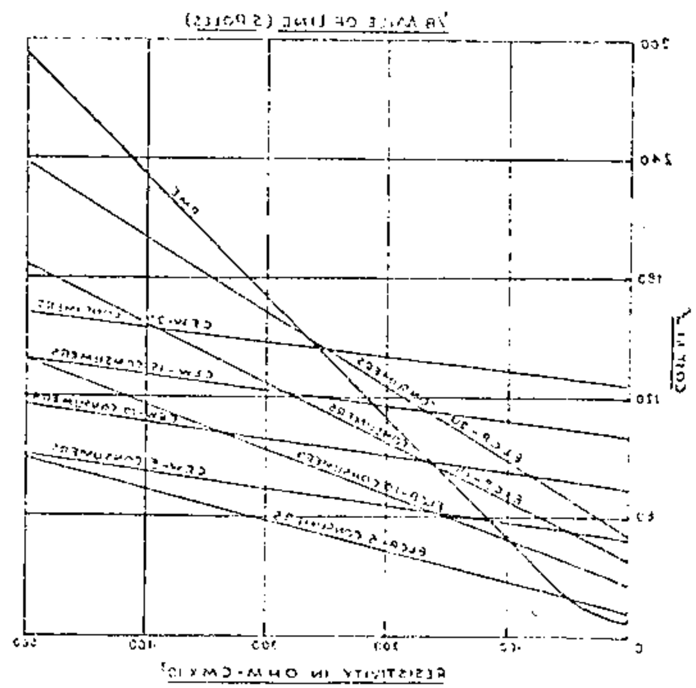


FIG. 6D

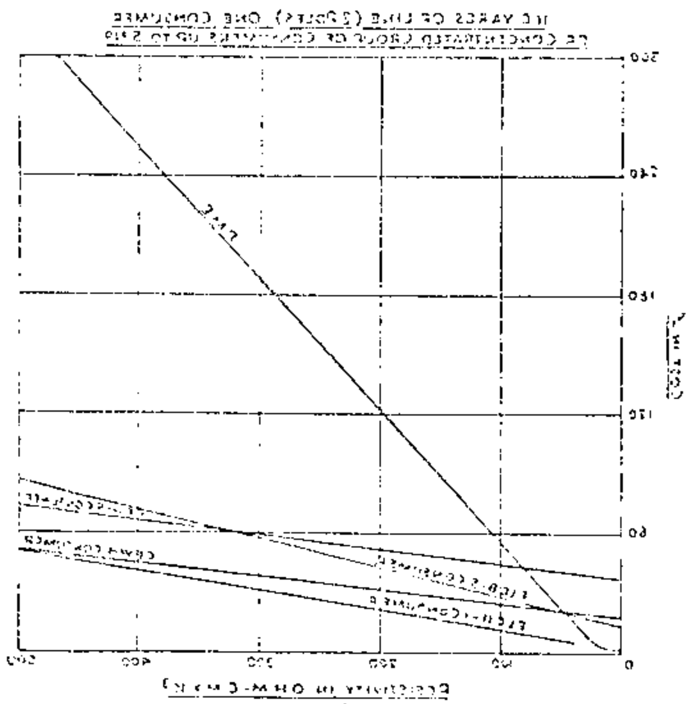


FIG. 6E

Note:—The cost of the PME method of earthing is based on the following:— The number of butt earths required to give the statutory 10 Ohm to earth of the neutral conductor and additional earth electrodes—0·058 sq. in. copper wire laid 2ft. in ground where these are necessary.

COMPARISON OF COST CEW, PME AND ELCB METHODS OF EARTHING

FIG. 6

The author wishes to thank the North of Scotland Hydro-Electric Board for facilities accorded to him for research. Also he would like to express his thanks to Professor R. O. Kapp and A. R. Pearson, Esq., for their helpful criticism in the preparation of the report.

Acknowledgement is made to Messrs. Kennedy and Donkin, Consulting Engineers, for permission to publish this article.

APPENDIX "A"

Testing of Earth Electrodes Using the Earth Megger

With the general adoption of protective multiple earthing as the main method of earthing of installations in the north of Scotland, testing of earth electrodes has become very important.

Butt earths and earth tubes have been tested in the north of Scotland and it has been found that with the use of certain ranges of megger, viz., 0–50 ohm and 0–500 ohm in high resistivity soils, correction factors have had to be applied to the instrument readings.

This is due to the potential spike of the test set assuming a very high resistance to earth value when used in high soil resistivity areas.

The difficulty experienced at the moment is that with the ranges of megger quoted above, the actual resistance to earth of the spike cannot be determined. Hence the correction factor formula, which involves the ohmic resistance to earth of the spike, cannot be applied.

Simple methods are being sought to measure the spike resistance to earth so that use may be made of lower range meggers.

Using the 0–3–30–300–3000 range megger a correction factor still may have to be applied, but unless the spike resistance to earth is greater than 3,000 ohm its actual resistance to earth may be determined by the use of the instrument.

WHITSUN BRIDGE

By Brigadier G. W. Duke, C.B.E., D.S.O.

" The Whitsun Holiday "
(extract from Divisional Routine Orders)

" *The Whitsun Holiday period will be from after duty on Friday 30 May to first parade 3 Jun 52.*"

SOME time on the Friday morning before Whitsun week-end, Driver Edward Liepiec drove proudly out of a R.E.M.E. armoured workshops in North Germany. He was proud because his transporter was laden with a beautiful, newly repaired Centurion tank, and his mission was to deliver it urgently to an armoured regiment engaged in a training exercise. His pride, unfortunately, was short lived, for he either selected or was ordered to use (history is obscure on this point) a route leading direct through Rotenburg. On the outskirts of this town the *Strassenbauamt* (road works authority) are rebuilding a demolished bridge, and for some time now traffic has been invited to use a diversion, which is bridged by a class 40 Bailey. Liepiec reached the centre of the first span of this bridge before Sir Donald's slide rule took charge and disaster occurred.

The bridge is 200 ft. long, consisting of two separate spans, of 110 ft. triple-single and 70 ft. double-single respectively, supported on a timber pile pier, with 10-ft. level ramps at each end. The equipment is normal (unwidened) Bailey which was handed over to the Germans after the war for semi-permanent replacements of demolished bridges.

As a result of Liepiec's efforts, the longer span collapsed in the centre, and folded down into the gap until it rested on the river bed about sixteen feet below road level. The water at the time was between two and three feet deep. One end of the bridge still rested on the timber pier, but the base plates had moved until they rested perilously on the edge of the cap stringers. The other end was pulled off the bank seat and down the bank towards the gap. One triple truss rested on the earth, the other on a large tree stump which was under the second bay. This gave the whole structure a cant to one side. The transporter remained quietly on the bridge roadway, but the Centurion " took fright " during the descent and gave a small sideways leap, ending up with one track on the top chord of one bridge girder, and the other in the middle of the transporter deck.

This situation was viewed with some amusement by the worthy citizens of Rotenburg, but a more serious outlook was taken by their representatives on the Watch Committee. These gentlemen naturally regarded with some gloom the abrupt closure of the main road between their town and Bremen, particularly as they knew full well that the nearest alternative good road involved a detour of about thirty kilometres. Their dismay was shared by the military authorities, and it was not long before the wires began to hum between Divisional Headquarters and the Divisional Engineers, who are stationed some forty miles distant from Rotenburg.

At this time we only knew that the bridge was broken, and that the German authorities estimated it would take six or seven days to rebuild. More details were required before a firm plan could be made. The action on Friday afternoon, therefore, was to send off a recce party, make preliminary arrangements for the supply of replacement bridging equipment, and warn the squadrons that the Whitsun holiday might not go quite as planned.

The recce party arrived on the site to find the R.E.M.E. recovery team at work. The recce officer watched with interest the process of hauling the tank back up the sloping bridge. The first critical moment was when the inner track fell from the transporter deck on to the bridge roadway. The tank then moved for about twenty feet with one track on the roadway and the other on top of the Bailey truss. Finally that track descended with a bump on to the ribands and the tank was then pulled safely along the roadway and off the bridge. Relieved of his burden, Liepiec drove his transporter on up the other half of the broken span, across some improvised decking over the centre pier, and away. This R.E.M.E. task was finished by Friday night, and the decks were now clear for the Sappers.

The bridge stood up well to the stresses of recovery, but it was of course in poor shape. It had failed in compression in the top chords, and all panels in the three centre bays were badly buckled. Every bracing frame in the span was crippled, and every raker was bent. Many of the transoms were slightly distorted, and some had the transom clamps bent so that they could not be removed.

The outline plan had to be made when the recce party returned on Friday evening. The situation was complicated by the fact that several officers and a number of other ranks had slipped away on week-end leave before the crisis really developed, and the Field Park Squadron already had a big stores commitment, as they were unloading vast quantities of pontoon bridging equipment for another project, which had inconsiderately arrived by rail on the Friday afternoon. Furthermore there was an Army Cup cricket match starting on the Saturday morning in which both the C.R.E. and the Adjutant were engaged.

It was not considered worth while to start clearing the wreckage in the dark, particularly as it was unlikely that any bridging equipment could be produced for use before Saturday afternoon at the earliest.

It was therefore decided to detail one Field Squadron to move out at first light with the task of stripping and removing the damaged span. While the C.R.E. was doing his Sir Francis Drake act on the cricket field, the second-in-command went out to examine the site in detail so that a firm bridging plan could be made. Before he had completed this task, the Divisional Commander arrived, and introduced a sporting note of urgency into the operation by laying down that a Class 40 bridge was to be open to traffic by last light on the following day, Whit-Sunday. This firm direction had been lacking in the original orders from Divisional Headquarters, who had merely told us to get on with the job of replacing the bridge, and it provided a most welcome operational aspect to the whole business. Armed with this information, the second-in-command returned post haste to base to confer with the C.R.E., who decided to abandon the cricket and get on with the job.

The bridging problem was an interesting one. The approaches at each end were on curved embankments off the main road, giving a building length behind the bank seats of barely forty feet at the north end, and just over fifty feet at the south end. The 110-ft. gap over the river (which has a summer width of about sixty feet) was full of wreckage, and the southern (70-ft.) span was still intact. The first plan, suggested by the original recce party, was to jack up and delaunch the 70-ft. span, and build the complete bridge from the end. On further consideration this was abandoned as being too complicated, and also because it involved considerable extra effort in disturbing an undamaged piece of bridge.

Having decided to build from the north end, the problem was to determine the best position for a pier. Its location was dictated to within twenty feet or so by the width of a sand spit in the river bed. At any other point in the gap it would have been difficult to level off and lay the grillage. The distance between the pier rollers and the bankseat could therefore be anything between thirty and fifty feet. Our first inclination was to build the pier as far out as possible, in order to ease conditions for the final launch of the completed bridge. But we at once realized that this would lead to a major crisis in launching out on to the pier during construction, owing to the very limited room for building behind the bank seat. With a fine sense of compromise, the final plan was for the pier rollers to be 40 ft. out, on the grounds that two minor balancing feats were more likely to be successful than one major one.

While these deliberations were going on, a second Field Squadron was loading up and moving out to the site. Their work, of course, could not start in earnest until considerable progress had been made with clearance of the gap.

The situation by midday on Saturday was that the gap clearing party had completed the stripping of all the decking, and had succeeded in extracting the transoms from the northern half of the bridge. The plan then was to cut the girders just at the water's edge, and haul them out with a Scammell, thus clearing a site for the pier. A welder, complete with oxy-acetylene cutting gear, was produced by the R.E.M.E. Workshops to avoid delay while the Field Park welders were mobilized and transported to the site, and this man did noble work throughout the rest of the day. This task was fairly straightforward and was completed without any major incident, although a telegraph pole had a very narrow escape when one of the girders fell over on its side while being hauled out

A more tricky problem was presented by the other half of the bridge, which had one end still resting on the centre pier, and the other in the river bed. It could not easily be dismantled, as a considerable length of the bottom chord and several transoms were under water, and buried in the sand of the river bed. It was therefore necessary to move this part in one piece, and the difficulty was to do this without damaging the pier. The solution adopted was to erect a skidway of transoms leaning against the cap of the trestle, down which the end transom of the bridge would slide. In this way the bridge girders would be prevented from dropping on to the trestle legs. The winch cables from a Diamond T and a Scammell were hitched on to the lower ends of the girders, and when all was ready, the order to take in was given. The bridge behaved beautifully and subsided quietly into the bed of the river without doing more than extracting a few loud groans of protest from the pier. The latter was watched carefully, even anxiously, during this operation and was reckoned to be still a good class 40.

As usual during the opening stages of these operations. time had passed all too quickly, and the shades of night were falling as the Field Squadron packed up and gave way to the setting out parties of the second Field Squadron who were now swarming over the site. Their task was to erect a pier, put in the bank seat, set out the launching plane, and have the rollers levelled and in position ready for bridge construction to begin when the first squadron reappeared on the scene at 0800 hrs. the next morning. It should be mentioned that both these "squadrons" were in fact operating at troop strength, with parties of approximately fifty all ranks.

While all this activity had been going on at the bridge, other hands had been busy on the provision of stores. This was by no means easy as all establishments had closed down and were working on a "duty officer" basis during the holiday period. Division had agreed to produce R.A.S.C. transport, and arrange for the collection of the necessary Bailey equipment from a German road maintenance depot. We therefore asked, early on Saturday morning, for sufficient stores to build 110 ft. of double-single bridge, to be delivered to the site as soon as possible. The estimated time of arrival of the convoy was given as 1800 hrs. on Saturday evening.

Bailey tools, sleepers for grillage, and a few Christchurch cribs were produced from our own field works stores, but as the final plan emerged during the day it became evident that we should have to build at least a 15-ft. pier, and more Christchurch cribs would be required. A small convoy was therefore dispatched to a R.E. bridging camp, some one hundred miles from Rotenburg, for the stores we could not provide ourselves. This party duly returned at 0245 hrs. on Sunday morning, just in time to avoid delaying the work. For this much credit must be given to the N.C.O. in charge, and no little praise too to Captain Sturt and the staff of the bridging camp, who arose and issued the stores at some ungodly hour on the Saturday night.

The first eight lorries of Bailey equipment arrived on time and were unloaded, but there was considerable speculation as to the fate of the other sixteen. This speculation turned to alarm on Sunday morning. The Sappers had worked nobly through the night, in spite of the rain, and by 0800 hrs. their task was complete except for a few finishing touches to the roller levels. The construction party had arrived and were ready to start building, but unfortunately all the sway braces were in the missing lorries, and there were none worth salvaging from the damaged bridge. However all turned out well, for shortly afterwards a 15-cwt. arrived which was the advance guard of the rest of the bridging column, and construction in fact started at about 0830 hrs.

The performance of this R.A.S.C. detachment deserves a special mention. They were turned out at short notice on the Saturday morning, twenty-four 3-tonners with two corporals in charge, and told to report to a German depot to load up Bailey bridging. On arrival they found that the German authorities had not provided any loading parties, as had been arranged, and at first only a caretaker was available. After some discussion a storeman was produced who was familiar with Bailey equipment, and he ticked off the items from his stocks, panels, transoms, stringers and all, which these stalwart drivers then loaded into their own vehicles. It is, therefore, hardly surprising that only eight of them were ready to move off on Saturday evening, and it reflects the greatest credit on all of them that the other sixteen turned up the next morning as they did. Had we known that this was going on we could, of course, have produced a loading party, but unfortunately the telephone system seemed to be suffering also from Whitsun fever, and the duty officer at Divisional Headquarters, with whom we were in constant touch, could never get any information from the German depot.

One other stores crisis had arisen during Saturday afternoon. The original request for stores for a double-single bridge had been made on the assumption that we would build a pier to remain *in situ* supporting the span. A detailed examination of the site, however, had shown that the construction of a semi-permanent pier would involve considerable work in preparation of the foundations, and in prevention against scour when the water level rose after rain. As we had neither time nor the necessary stores for such work it was decided to build a temporary pier for launching purposes only, and dismantle it afterwards. This meant that the bridge would have to be built of triple-single construction, whereas we had only ordered stores for double-single. We therefore had to salvage such items as were serviceable from the old bridge, and arrange to make up the rest from our own regimental stock against replacement from the German depot later. In fact it was found that only a few panels and a couple of end-posts had to be supplied in this way.

With the arrival of the second lot of bridging on the Sunday morning our administrative troubles were at an end, and it became a straightforward race against time. There was much to do. Apart from the construction of the new bridge there was still some seventy feet of wreckage in the river, two mangled girders lying where they had been dragged on the north road approach, a pier to be dismantled, and a mass of small stores to be loaded up so as to leave the site clear.

The C.R.E. had returned home late on Saturday night, partly to get some sleep and partly to look in on the Wives Club Witsun Dance, which had been somewhat denuded of husbands by our friend Liepiec. At the dance he met one Major Stanley who commands a German Service Organization labour unit, and then and there, over a glass of beer, he arranged for Major Stanley to produce fifty of his Germans the next morning. He also took the opportunity to warn the remaining Field Squadron that they would have to find a working party during the day.

The G.S.O. detachment were the first to arrive, and they were put on to the wreckage in the river. Although none of them had ever seen Bailey equipment before, they soon got the idea, and during the morning they reduced the bridge to its lowest terms, or at least to the state where it could be torn to pieces by dozers and then hauled out of the river. By 1530 hrs. the river was clear, and all that remained was to strip the girders, and load the components on to the R.A.S.C. lorries for return to the German depot. These fellows undoubtedly put up a very fine show.

The third Field Squadron detachment arrived at about 1400 hrs., and made short work of the girders lying on the north approach road. They then stood by, waiting for the launching of the bridge to be completed so that they could work on the pier and dismantle it.

The bridge construction party had a slow start owing to the height of the bank-seat rollers. This was unavoidable for two reasons; firstly, as the bridge had level ramps, the rollers had to be given sufficient height to prevent the tail grounding, and secondly, allowance had to be made for the sag of the bridge during launching. In addition we had decided to arrange the launching plane so that the launch was slightly down hill. Once the first two bays were established the only worry was caused by the very short building space, particularly during the stage just before launching on to the construction pier. However, the levels worked out all right, the counterweights were correct, and all went well.

As soon as the bridge was down on to the central pier baseplates, and the construction pier rollers had been taken out, one party set about dismantling the construction pier, while another started on the tedious business of jacking down. This began at about 1730 hrs. and took nearly three hours, owing to the height at which the bridge had to be built.

It was during this stage that the local inhabitants started to take a serious interest in the prospect of the bridge being reopened to traffic. Until fairly late in the afternoon, there had been little to show for our efforts, but once the bridge had been launched across the gap, various officials started to appear on the scene. The most important was one who was never completely identified, but who was clearly an equivalent of the Borough Surveyor. On his first visit, this gentleman inquired whether the bridge would be ready for traffic the following morning, and on being informed that it would be open that night he was frankly incredulous. However, he returned later with a couple of old men to relay the granite setts in the road approach, which showed that his confidence was increasing.

The bridge was in fact completed at 2055 hrs., except for a short length of skin decking which we had been unable to lay owing to shortage of timber. This was obtained by cutting up damaged chesses, and the bridge was ready for traffic at 2200 hrs. The Borough Surveyor had meanwhile telephoned to his boss in Hanover, who evidently told him to inspect the bridge the next morning to ensure that it was fit for traffic. Just as he was telling this story to the C.R.E. an enormous civilian bus appeared, containing the members of a sergeants' mess outing. After some parley with the Borough Surveyor and the police this bus was allowed to cross the bridge, which it did to the cheers of the assembled Sappers. With this precedent established, the authorities bowed to the overwhelming public demand, and opened the bridge straight away to all comers.

The Divisional Engineers thus just fulfilled their contract, having cleared the site and rebuilt the bridge in two days, and they returned to barracks tired but happy.

Whitsun Bridge

RERAILING W.D. LOCOMOTIVE IN THE SUEZ CANAL ZONE

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

HISTORICAL

THE present unsettled state of affairs in the Suez Canal Zone of Egypt can be dated back to 16th October, 1951, from which date the Egyptian Government exhorted its peoples to adopt a policy of non-co-operation with the British Army.

For just over a year prior to this date 10 Railway Squadron had operated a main-line W.D. freight service throughout the zone, using its own locomotives and rolling stock. These trains were manned by military personnel, but the Egyptian State Railways provided a pilotman. In August, 1951, prior to this date, the Egyptian State Railways had specially requested the British Army to withdraw this service, and in view of political tension between the two countries it was, in fact, withdrawn. However, with the advent of non-co-operation, it became necessary to ensure that military stores and equipment were moved about the Canal Zone as and when required. A considerable amount of passive resistance was met with by the Railway Squadron when it carried out this requirement. This passive resistance gradually turned into a more active type and took the form of culverts being blown up, signal boxes sniped at and short pieces of rail blown out of the track etc., but at the onset in a very amateurish way. This was not to last, however, and on 15th December, 1951, at approximately 0730 hrs. the first really major attempt to disrupt W.D. military traffic occurred. A W.D. train routed from Adabiya to Nefisha was derailed by terrorists at El Zeitiya, 3 miles south-west of Suez. The train was being hauled by an ex L.M.S. Class 8 locomotive (wheel arrangement 2-8-0, W.D. Number 70387, now 503), carrying the nameplate "Corporal W. J. Lendrim, V.C., R.E.," which was overturned complete with tender, and the first seven vehicles which were also telescoped.

Due to the considerable disruption caused by the derailment to the track and formation, no accurate proof could be obtained to show the exact cause of the derailment, but it can be assumed that either fishplates and a length of rail had been removed, or that a portion of the track had been demolished by an explosion. The train is known to have been travelling at 25 m.p.h. and the locomotive came to rest on its side some sixty yards from the assumed point of derailment. All the track over this length was torn up and the formation disturbed by the leading wagons ploughing their way through.

Photo 1.—The derailed train and original diversion in use.

Photo 2.—The telescoped tender being cleared from the loco cab by means of S.W.R. attached to another loco. Gantry erected for lifting loco.

Retailing WD Locomotive in the suez canal zone 1,2

Site Conditions

The alignment at the site of derailment is straight. The main-line track is single line and built with flat bottomed rails on wooden sleepers and ballasted with local soil. The track is on an embankment 3 ft. above the general ground level. A siding line runs parallel with the main line at 30-ft. centres and is also on an embankment. The locomotive, tender and some of the wagons came to rest in the valley formed between the two embankments. (Plan "A" and Photo No. 1.)

The surrounding ground is low lying, swampy and subject to flooding at spring tides and after heavy rain, and consists of sandy clay soil, approximately three feet thick, overlying a sand subsoil. Considerable rainfall occurred in the four weeks following the derailment. The open drainage channels on either side of the main line were damaged and blocked, and it was subsequently found that a close-jointed pipe conveying sullage beneath the tracks had been completely severed. Although attempts were made to divert the sullage, the contents were seeping into the ground beneath the wreck. The main drainage channels from the area fall directly into the sea and are also subject to tidal variations, and consistently became blocked with waste products from the near-by oil refinery and other local refuse. Despite the close attention paid to the drainage work carried out during the reclamation of the damaged stock, the standing water level throughout the area was never lowered more than 6 in. below general ground level.

Action

Due to the pressing need to maintain rail communication between Adabiya and the remainder of the Canal Zone, it was essential for immediate steps to be taken to provide an alternative track, as the removal of the derailed stock was likely to take several weeks, owing to there being no breakdown cranes available. It was decided that the adjacent siding should be utilized and connected to the main line south of the derailment. This involved the construction of an embankment of approximately 300 cubic yards, the material to be obtained from the immediate vicinity. Two D.7 bulldozers were obtained to assist in this construction, but due to the softness of the surrounding ground, these machines could not be used to the best advantage, although they were successfully used to construct a temporary access road from the main road to the derailment site.

To complete the construction of this embankment and the subsequent connecting of the track by manual labour, the services of twenty Mauritian troops and a company of the Royal Sussex (110 men) were obtained to assist the fifteen sappers who were available from 10 Railway Squadron. The link through was completed at

1200 hrs. on Monday, 17th December, 1951, and the first train passed the site immediately the line reopened. To ensure complete structure clearance, the corner of the roof of a 40-ton box wagon had to be removed by flame cutting.

TABLE OF HOURS WORKED

	10 Railway Sqn.		Royal Sussex Regt.		Mauritians	
	Hrs.	Men	Hrs.	Men	Hrs.	Men
Saturday 15th December ..	17	15	—	—	5½	20
Sunday 16th December ..	17	15	9	110	7	20
Monday 17th December ..	5	15	—	—	—	—

CLEARANCE OF DAMAGED WAGONS

The clearance of the seven derailed wagons was effected by the use of a 10-ton mobile crane of American design, mounted on caterpillar tracks, obtained by the Transportation Directorate at G.H.Q., M.E.L.F. After an overhaul, this was brought to the site by road transport, but due to consistent electrical and mechanical trouble, caused by the lack of suitable spare parts, the crane did not commence work until 25th February.

Prior to this date, however, a sleeper roadway was constructed on the strip prepared by the bulldozers earlier, to allow easy access to and from the site and to allow the crane to move forward along the formation of the main line as the clearance of wagons proceeded.

Two craftsmen of R.E.M.E. were allotted the task of removing all salvageable fittings and cutting free those parts of the stock likely to cause obstruction when lifted by the crane.

All of the seven wagons were damaged to a degree that prohibited their rerailing and removal from site by locomotive. As the line capacity and locomotive availability would not allow the continual use of engine power to stand on the site with empty wagons to receive each lift made by the crane, the following method was adopted.

The wagons were lifted in such component parts as could conveniently be arranged, subject to the limitation of the crane, and placed on either side of the crane track as it moved forward along the line of wagons (see Plan " A "). At a later date all the parts of the wagons were loaded on to a train of empty wagons with the minimum of delay to traffic, and taken to railway workshops for disposal. By this method, the crane was able to deal with five wagons before a large crater formed by Flat wagon No. 346, which had nosed into the formation at the point at which the close-jointed pipe crossed the track, stopped progress along the route.

To remove the remaining two wagons it was, therefore, necessary to take the crane along the line of the diversion track until alongside the wagons. This was done at a later stage when the diversion track had to be slued away from the locomotive to facilitate the removal of the latter, thereby leaving sufficient clearance to stable the crane between the wagons and the running track.

Great care had to be exercised when movements of the crane were made, due to its weight, and at all times a fully sleepered roadway had to be laid to ensure that there was no risk of the crane sinking in the poor soil.

Locomotive Recovery (Plan One)

As Locomotive No. 70387 had only left railway workshops one day prior to the derailment after a complete overhaul and, from such inspection as could be made in the position in which it was lying, there was no apparent severe damage, it was a requirement that the locomotive should be raised complete and with as little damage as possible.

To achieve this object it was decided to construct two reinforced concrete rafts beneath the locomotive to be used as jacking platforms. With the aid of four 50-ton jacks, the locomotive was to be raised sufficiently to allow a bed of sleepers to be inserted below the locomotive, and then the four jacks could be used to commence the overturning movement using timber packings.

Before the construction of the concrete platforms could proceed, it was necessary to carry out certain preparatory work to ensure maximum stability of the surrounding ground. On the diversion track side of the locomotive, it was decided to drive steel sheet piling parallel with the track alongside the locomotive and tender, to maintain the stability of the running track, as the excavation of soil from around the locomotive would otherwise seriously weaken the embankment. It was also necessary to slue the diversion track away from the locomotive by 3 ft. 6 in. to ensure adequate working room. This involved the tipping of soil on the side of the embankment over a length of 200 ft. requiring approximately one hundred cubic yards of material. A further task was the construction of "cut-off" drains in the agricultural ground that lay on the north of the site, in an endeavour to stem the flow of water in the subsoil before reaching the working area. (See Plan "B.")

To carry out these tasks the services of 50 Field Squadron, R.E., were obtained and a working party of either Infantry or Mauritian troops was provided. The Field Squadron concentrated on the task of driving 12-ft. sheets of " Larsen " piling, using a pile frame constructed by the D.C.R.E. Suez in accordance with the light frame recommended in the *Manual of Field Engineering*, utilizing an 11-cwt. monkey and the power winch of a D.7 tractor. The frame and power unit were mounted on a flat wagon and the monkey guides extended below the floor of the flat to within 6 in. of rail level, to facilitate the maximum depth of drive. The wagon was stabled on a near-by siding and piling operations were carried out in occupation times between trains, the wagon being moved into position from the siding by utilizing the winch rope of the power unit attached to conveniently located holdfasts. The working parties were engaged in the construction of the embankment extension and the cut-off drains.

At the end of January it became evident that the construction of concrete rafts below the locomotive would become a major engineering operation involving the continual use of dewatering pumps and the complete encirclement of the locomotive and tender with sheet piling, as the efficiency of the " cut-off " drains was not as great as had been expected. The drainage had considerably lessened the amount of water flowing toward the site and conditions had improved, but from a few trial holes which were dug it was evident that the subsoil was so water-logged that any excavation would only cause the locomotive to sink deeper into the mud.

Locomotive Recovery (Plan Two)

Faced with the difficulties stated, an alternative scheme was formulated which involved the construction of two gantries over the locomotive, utilizing light steel trestling. Using four 20-ton Morris blocks and tackles, the locomotive would be raised into an upright position. To lighten the load as much as possible, the motion on the upper side and the pony wheels were removed. The necessary stores were located and release obtained by Transportation Directorate. Delivery of the material commenced in the middle of February. At this time a change in location of field units took place, and at a site meeting held on the 22nd February, it was agreed that 3 Field Squadron, R.E., should now undertake the construction of the gantries, and assist 10 Railway Squadron in any other such works as might be necessary. It was subsequently agreed that 3 Field Squadron should also be responsible for raising the locomotive into an upright position. The detailed division of responsibility for the various phases of the job is given at Appendix " A."

To support the south-side piers of the two gantries advantage was taken of the sheet piling already placed under Plan One. It was considered necessary for the movement of normal rail traffic that a completely new diversion track should be made to allow the construction of these piers. The building of this further diversion involved the construction of another embankment of approximately 350 cubic yards, and infantry working parties were made available for this work.

Raising of Locomotive

3 Field Squadron, with advice from 10 Railway Squadron, planned to pivot the locomotive on the lower driving wheels. It was considered that no damage would occur to the wheels or the main frame. It was never established where the centre of gravity lay, but working on the assumption that its position was as shown on Plan "C" attached, it was estimated from scaled drawings that the locomotive would reach the point of balance at about 60 deg. from the horizontal.

The Morris blocks which were available were two 20-ton and two 15-ton tested to 22½ tons. It was, therefore, decided that as the greater proportion of the weight of the locomotive (65 tons approximately) would be at the firebox end, to use the heavier blocks at the rear, and the lighter ones at the front. The two types of blocks were of different ratios, and no strain gauges were available in the Canal Zone to ensure equal distribution of the weight on each tackle, and, therefore, it was not possible to record the actual power required to lift the locomotive. It was hoped that even distribution could be achieved by watching the power exerted by each of the two pulling teams, and then taking up the necessary turns on the easier tackle, thus redistributing the load evenly. This, in fact, was quite successful. There was no means of estimating the drag caused by suction, but it was hoped that this would not exceed 10 tons.

It was planned to pack as lifting proceeded, but it was realised that after 40 deg. it would not be possible unless cribs and specially cut timber were used in bracing back to the sheet piling. It was decided that packing would be dispensed with after 40 deg. The plan envisaged the two far blocks taking over the weight at the point of balance and lowering the locomotive to its upright position.

In the derailment, the tender had telescoped into the cab of the locomotive, and before the lifting operation could begin on the locomotive, it was essential that the tender should be withdrawn a minimum of 18 in. clear of the locomotive. This was achieved utilizing S.W.R. and two sheave blocks and a 0-6-0 shunting engine. The tackles were made fast to a palm tree stump which was found to be capable of taking the load required. (See Plan "B.")

Two gantries were constructed, with headroom 20 ft. from the lower wheels of the locomotive to the underside of the gantry girders. Each gantry consisted of two towers of "L" trestling and two

24 × 7½ in. R.S.Js., 40 ft. long, supporting two sets of Morris blocks and overhead attachments. These attachment sets were supported on flat bottomed rails spot-welded to the top flanges of the R.S.Js. and the rails used as skids to enable the tackles to be traversed by means of jacking, thus keeping them in a vertical position as the locomotive was pivoted about the lower wheels.

Two pairs of 3½-in. S.W.R. strops, of measured length, were connected to each of the two Morris blocks for the initial lift, and connected to the underside frame of the locomotive by means of hooks. Points of connexion were (*a*) at a point on the frame between the two rear driving wheels and (*b*) at a point on the frame in front of the forward driving wheel. The strops were passed under the locomotive and round the firebox in the case of (*a*) and round the boiler at the junction of the smoke box and boiler in the case of (*b*).

Two further pairs of 3½-in. S.W.R. strops, of measured length, were connected to the other Morris blocks to take over the locomotive at the point of balance, which was estimated to be between 60 and 65 deg. from the horizontal. Attachments of the hooks in this case were made at similar points on the frame as previously mentioned, but on the topside frame.

A 25-ft. length of "Larsen" steel piling was placed longitudinally under the pivot wheels to reduce the amount of sinkage. This proved quite a success considering that it was "floating" on water table level. When the locomotive was lifted upright, the upper set of wheels were lowered into another 25-ft. length of steel sheet piling.

The lifting operation was completed in two days. On the first day the locomotive was raised through approximately 25 deg. and then left overnight resting on packing. On the following day the lift was completed, packing following the lift up to 40 deg. From then on it was not possible to use packing, as the angle was too acute. The locomotive reached the point of balance at approximately 63 deg. This part of the task was completed on 26th March, 1952.

Rerailing and Disposal of Locomotive

Prior to the actual lifting of the locomotive, a temporary track, on which to haul the locomotive from its position beneath the gantries, had been constructed as shown on Plan "B." When the locomotive was lifted upright and the wheels placed in the two lengths of steel sheet piling there was a considerable sinkage at the leading end. It was, therefore, necessary to lift the entire locomotive using the four lifting tackles and four 50-ton hydraulic jacks and to place timbers longitudinally in the sheet piling to obtain a stable bed. Sleepers were then placed transversely across these timbers to carry F.B. rail and the whole was connected to the approach track which had already been constructed.

The damaged locomotive was inspected in this position by locomotive fitting staff and all moving parts well oiled before it was hauled out. This was done by using another 2-8-0 locomotive and a length of 3½-in. S.W.R. Locomotive No. 70387 was then taken in tow and removed to Railway Workshops at Suez for overhaul on 31st March, 1952.

Recovery of Tender

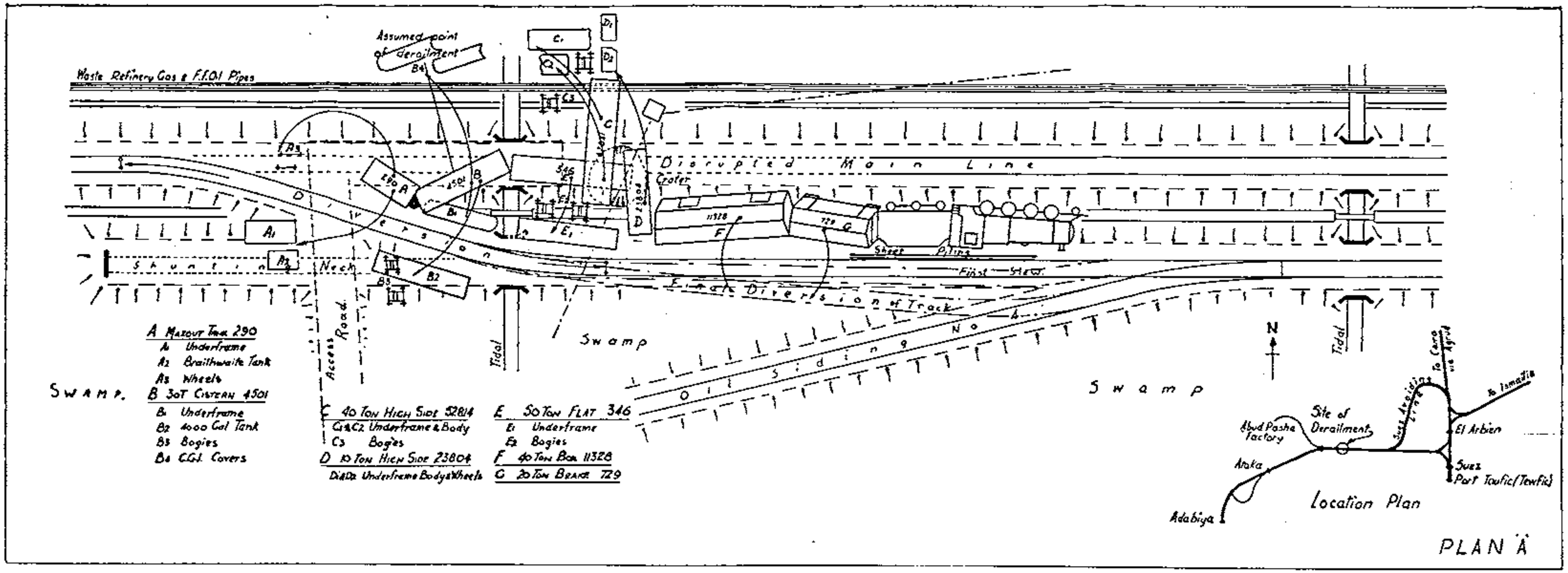
After the removal of the locomotive from the site, the tender was raised by the following method. A sleeper platform was constructed alongside the tender and steel piling channels laid along the length in the position that the top side wheels would take when righted. The S.W.R. and tackle utilized previously were anchored to a group of small palm trees at right angles to the tender, and the running end attached to the cable of a bulldozer winch as shown on Plan "B". Attachment was made from the tackles to the lifting eyes provided on the tender, and the 10-ton mobile crane was used to assist in the overturning motion. When righted, the tender was held in position by the crane and tackles with the wheels resting in the steel piling channel, whilst another timber crib was built below the other wheels. The tender was then lowered down into another set of channels in an upright position. Further lengths of channel were then placed to lead the tender on to the track that had previously been constructed beneath the locomotive. The tender was hauled on to this track by the winch of the D.7 bulldozer and sent to Railway Workshops on 3rd April, 1952.

Clearance of Site

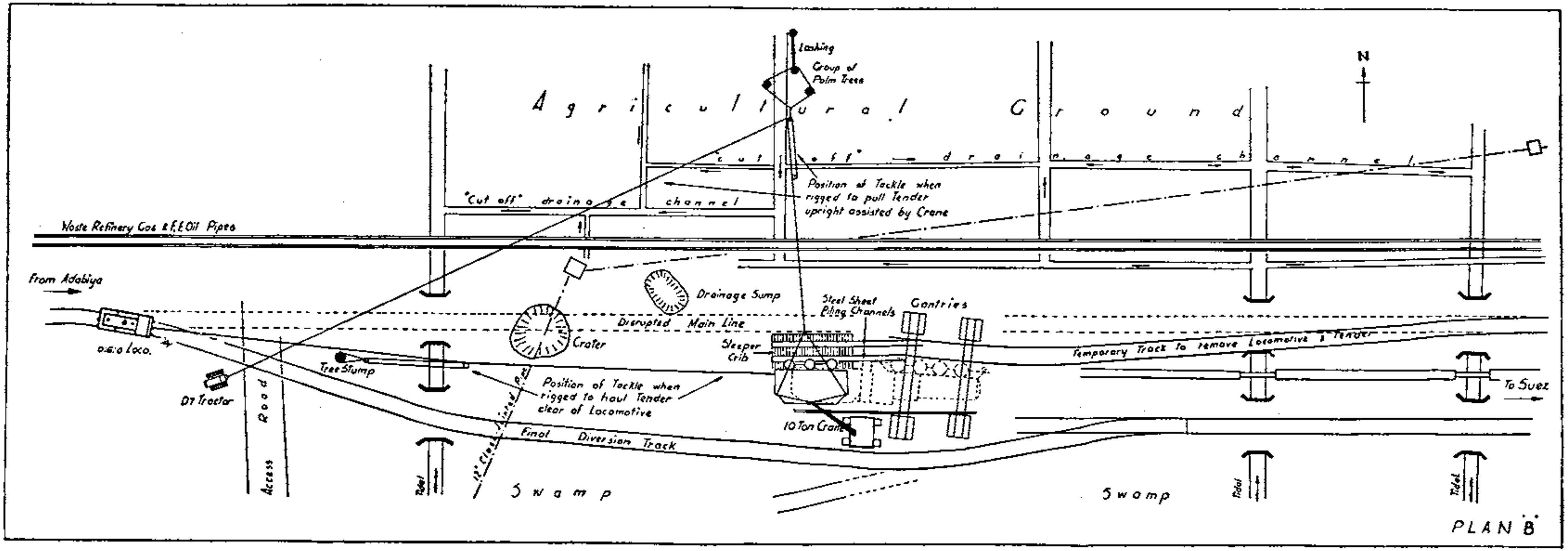
The removal of all materials and stores used in the reclamation of this derailment was commenced immediately the tender had been removed. Sappers of 3 Field Squadron dismantled the gantries with the aid of the 10-ton mobile crane and Sappers of 10 Railway Squadron, assisted by a party of East African Pioneers, loaded the materials into rail wagons for disposal.

The site was completely cleared of all W.D. stores and the permanent infantry guard, which had been mounted on the site since the derailment, was stood down on Saturday, 19th April, 1952. Reinstatement of the old alignment was left to the Egyptian State Railway.

It will be of interest to note that Loco. No. 70387 was back in service by May, 1952.

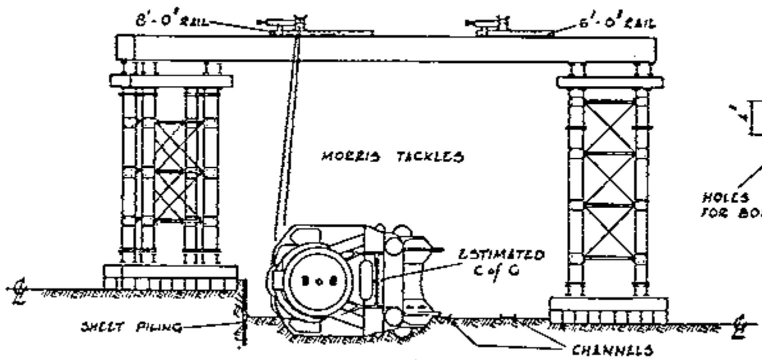


Assumed point of derailment
Waste Refinery Gas & F.E.Oil Pipes
Disrupted Main Line
Crater
Diversion
Shunting Neck
Access Road
Sheet Piling
First Slew
Final Diversion of Track
Oil Siding No 4
Tidal
Swamp
SWAMP.
A Mazout Tank 290
A1 Underframe
A2 Braithwaite Tank
A3 Wheels
B 30T Cistern 4501
B1 Underframe
B2 4000 Gal Tank
B3 Bogies
B4 C.G.I. Covers
C 40 Ton High Side 52814
C1&C2 Underframe & Body
C3 Bogies
D 10 Ton High Side 23804
D1&D2 Underframe Body & Wheels
E 50 Ton Flat 346
E1 Underframe
E2 Bogies
F 40 Ton Box 11328
G 20 Ton Brake 729
N
Location Plan
Adabiya
Ataka
Abud Pasha Factory
Site of Derailment
Suez Avoiding Line
To Cairo via Agrud
To Ismailia
El Arbien
Suez
Port Toufic (Tewfik)
PLAN A

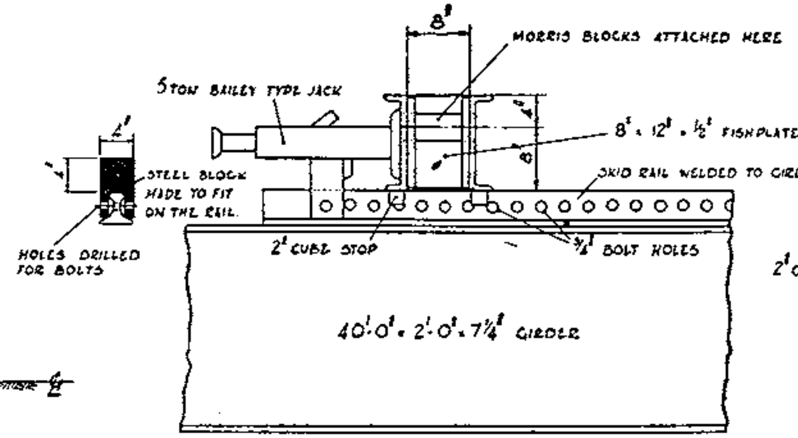


Lashing
Group of Palm Trees
Agricultural Ground
N
"Cut off" drainage channel
Position of Tackle when rigged to pull Tender upright assisted by Crane
Waste Refinery Gas & F.E.Oil Pipes
From Adabiya
0-6-0 Loco.
D7 Tractor
Access Road
Tree Stump
Crater
Drainage Sump
Disrupted Main Line
Steel Sheet Piling Channels
Gantries
Sleeper Crib
Temporary Track to remove Locomotive & Tender
To Suez
Position of Tackle when rigged to haul Tender clear of Locomotive
12" Class Lined Pipe
10 Ton Crane
Final Diversion Track
Tidal
Swamp
PLAN B

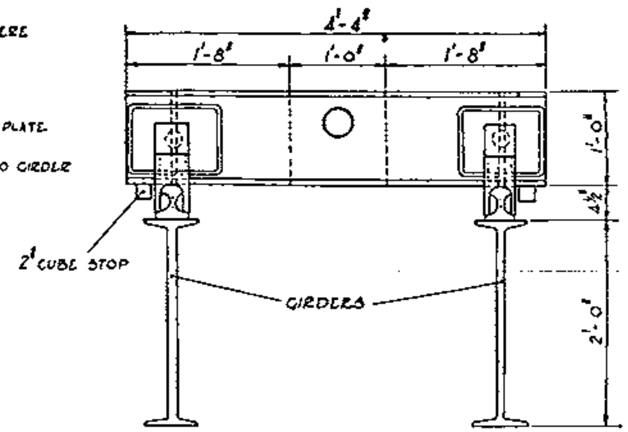
RECOVERY OF ENGINE NO. 70387 (CPL. W. J. LENDRIM V.C. R.E.)
AT EL ZEITIYA CANAL ZONE
M.R. 76138070 SUEZ SHEET 80/72



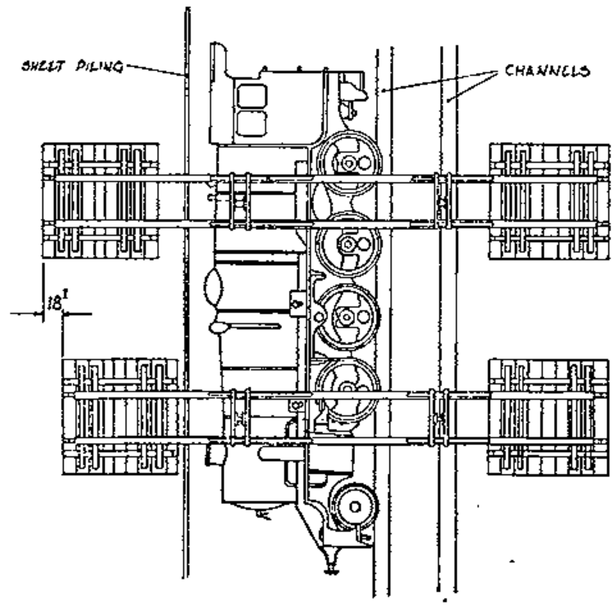
ELEVATION



FRONT ELEVATION



SIDE ELEVATION

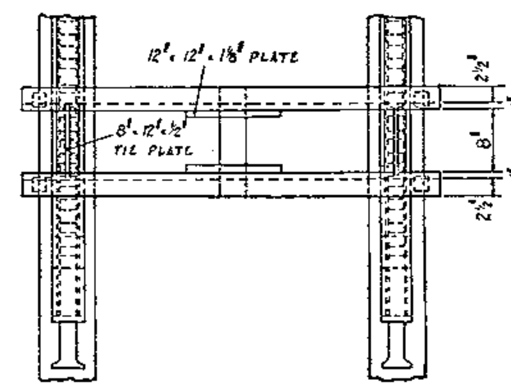


PLAN

DETAILS OF OVERHEAD ATTACHMENT SETS

inches 6 6 0 1 2 3 4 feet

Scale



PLAN

SCALE - feet 10 5 0 10 20 30 feet

PLAN "C"

APPENDIX "A"

Division of responsibility for Salvage from 23rd February, 1952, to finish

Task	*Unit*	*Assisted by*
Clearing damaged wagons	10 Rly. Sqn., R.E.	53 Port Sqn., R.E. (Crane), R.E.M.E.
Movement of tender to facilitate lifting of locomotive	10 Rly. Sqn., R.E.	53 Port Sqn., R.E. (Crane), 3 Field Sqn., R.E.
Construction of two gantries and lifting locomotive to vertical	3 Field Sqn., R.E.	10 Rly. Sqn., R.E., for assistance and tech. advice
Construction of temp. track for locomotive removal	10 Rly. Sqn., R.E.	3 Field Sqn., R.E.
Removal of engine	10 Rly. Sqn., R.E.	—
Lifting of tender	10 Rly. Sqn., R.E.	3 Field Sqn., R.E., 53 Port Sqn., R.E. (Crane)
Removal of tender	10 Rly. Sqn., R.E.	—
Dismantling of gantries	3 Field Sqn., R.E.	53 Port Sqn., R.E. (Crane)
Clearance of site and disposal of stores	10 Rly. Sqn., R.E.	53 Port Sqn., R.E. (Crane)

THE STATION-MASTER AT HAMM

Minefield Breaching Regardless of Casualties

By Major M. L. Crosthwait, M.B.E., R.E.

" Of what use would be tin triangles and the like against an enemy—if there be such a one—who ignores mines and accepts casualties."

THE marshalling yards at Hamm lie to the south-west of the town. From where the duty officer was sitting in the L.C.V. they were clearly visible on the map pinned up on the side of the vehicle. It is popularly believed that the same man held the job of station-master throughout the war. A tiring but interesting time he must have had, thought the duty officer. He had many opportunities to put his air-raid precautions and his arrangements for repair into operation. He could see how one plan worked and adjust it for the next time. Rather like that chap at " Duffers Drift."

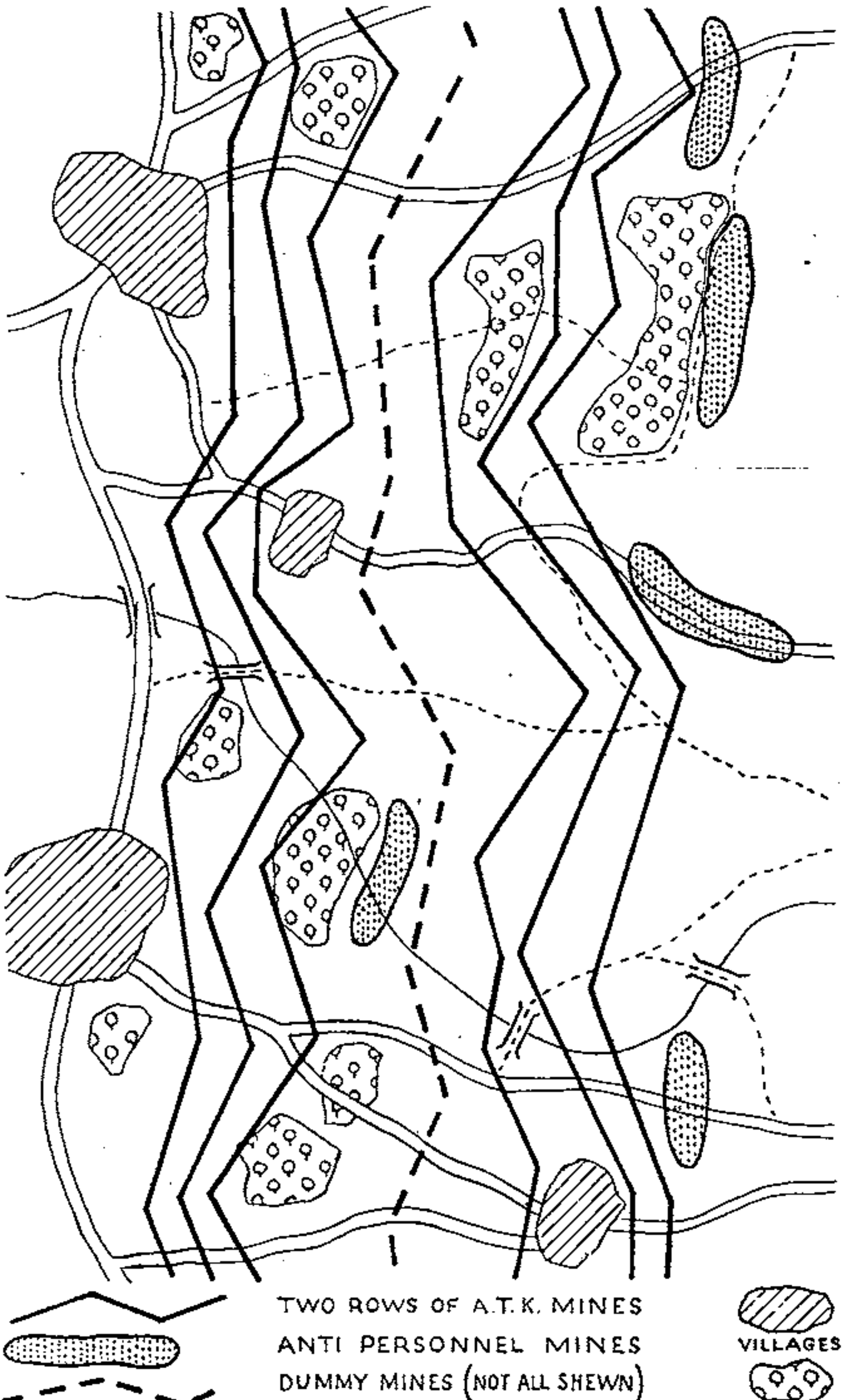
Dismissing the mental picture of the station-master from his mind, the duty officer looked again at the layout of the minefield on the large-scale map in front of him.

The plan necessitated the construction of a stop line for a distance of about five miles. The country was agricultural, open and flat with only a few woods and villages scattered here and there. A minefield, defended by well sited, well dug and well concealed infantry positions was the only answer. This work was now going on, its scope being limited only by the time and mines available.

Sketch 1 shows the essentials of what the duty officer saw. The minefield was in considerable depth—800 yards or so and sufficient mines were to be laid to achieve a density of two mines per yard over the whole front. In general there were six rows covering about 200 yards in depth and then a gap of about 400 yards followed by another six rows. Dummy rows were to be laid in the middle. These would contain the same sort of tracks and marks as the real field and would show up similarly on an air photograph. It was hoped that it would give the field an illusion of great density as well as depth.

The mathematicians say that even one mine per yard of front should cause a very high proportion of casualties, so that this minefield, with its depth and density, had every chance of keeping the enemy out. Admittedly the numbers available to man the defensive positions (which were sited behind the minefield) were far from numerous, but at least the main approaches could be covered in reasonable strength. Its depth made it difficult to breach in one night and anti-personnel mines had been liberally used (see Sketch 1). The duty officer felt that all was well. An enemy tank was unlikely to rumble up to his harbour area unheralded.

SKETCH 1



In each sketch 1,2&3 the number of mines laid is the same.

NOT TO SCALE

The First Attack

It was two days before the enemy attacked. The work on the position had been finished and the defences manned. The gaps through the field had been well and truly closed by cratering and mining after the covering forces had withdrawn through them.

The speed at which the attack developed took the defenders by surprise. The duty officer himself was in one of the forward O.Ps. and was able to see for himself. It was known that the enemy was approaching in considerable strength. Two reconnaissance tanks had already been blown up on the front edge of the minefield so that the enemy could be in no doubt that the minefield was there, even if he had not already discovered it from air photographs. The defenders had such confidence in the mathematicians that they hoped the enemy would try a massed armoured attack. But shortly after dawn on the second day things went a bit differently.

Visibility was not good. Although the enemy artillery was in no great strength, as he attacked very soon after his forward elements had discovered the minefield and there had been insufficient time for him to deploy all his supporting weapons, it fired mostly smoke both on and behind the mined area. It was difficult therefore to get an uninterrupted view. As the enemy tanks started to advance, some took up hull-down positions on the far side of the field and kept up a continuous fire at likely defensive positions. Others advanced straight at the field. Each of these was preceded by two men on foot. These men were each armed with a prodder and one walked in front of each track.

Hand Clearance

They prodded swiftly as they came. Where it seemed unlikely that any mines had been laid they advanced at a quick walk. Where they thought that mines might be, they prodded. If they found a mine it was pointed out to the tank driver and a little flag was stuck in the ground to mark it. Each man carried a lot of these flags stuck in his belt. If one of these men was hit or if he walked on an anti-personnel mine, another, who had been sheltering behind the leading tank, took his place.

Immediately behind the leading tank and its accompanying replacements for the pathfinders, there followed another tank in the tracks of the first. Behind this tank was a party which uncovered the mines marked by the flags and lifted them by hand. If a mine was booby trapped more men, sheltering behind the third wave of tanks, came forward to take the place of those killed. The gap, as this party proceeded, was marked by green tapes.

The duty officer as he watched through the smoke and haze felt extremely annoyed. This was not what they had planned for. Although for every mine found and cleared perhaps three enemy soldiers were being killed, the tanks were coming on through the field. One or two were blown up on mines that had been missed, but others were guided round to take their place. In the particular sector that he was watching, six or seven columns of tanks, each column spaced about seventy to a hundred yards from the next, were slowly working their way forward.

When the leading tanks were about half-way through the field, they came under fire from the anti-tank guns, firing from defiladed positions. Two tanks were quickly knocked out. The ordered formation of the advancing tanks was then broken. Branching left and right along the field, the leading tanks made use of the folds in the ground and soon two or three had safely found hull-down positions from which they could observe and return the fire of the defenders.

The dummy minefield in the middle was useless as it had been merely neglected. The enemy had taken a chance and scattered within the field. "Of what use would be tin triangles and the like against an enemy—if there be such a one—who ignores mines and accepts casualties?"* Of what use, indeed?

Some tanks ran on mines, but if their guns were still in action they were soon set alight by fire from the defending anti-tank guns. But in so doing the guns gave their positions away to those tanks which had found concealed positions, and several of the guns in their turn were knocked out.

Finally under a hail of well-directed fire from the near-by tanks, and helped by artillery concentrations, a mass of enemy infantry surged forward over the last rows of mines, storming up to the defenders' positions. The duty officer felt most uncomfortable.

Second Thoughts

"Excuse me sir, you are wanted on the set."

The duty officer woke with a start. The map of the positions was still in front of him. With hands shaking slightly he picked up the headphones and began to speak.

When he had finished speaking he turned to the plan again . . . The station-master at Hamm . . . What would he have done? Did he also sometimes dream?

The duty officer started to ponder. Could the enemy really attack like that? Would he really be willing to sacrifice three or four men for each mine lifted to make a gap? If he did attack like that, what changes should they make in the plan? Too late now, of course, but what could they have done?

* See "Tin Triangles" in the December, 1952, *R.E. Journal*.

The duty officer jotted down the following points.

(1) One mine per yard of front was all very well mathematically, but in fact it meant that only about four or five—at the most six—need be lifted to make a gap. The rear rows, being close to the defenders' positions had played no part in this battle.

(2) Depth still had to be achieved, but if there were large areas within the field, which were unmined, any tanks which had penetrated had some power of manœuvre, and could take up good fire positions inside the minefield.

(3) More anti-personnel mines were required and these would best be laid within the field.

(4) The enemy attack still might come anywhere and therefore the whole front must be covered.

(5) Some D.F. tasks should be arranged to come down in the minefield itself.

(6) There should be some infantry positions well forward within the field. These should be held by few men, be excellently concealed and be capable of a very high rate of fire.

Based on these points, the duty officer drew a new plan for the minefield (see Sketch 2).

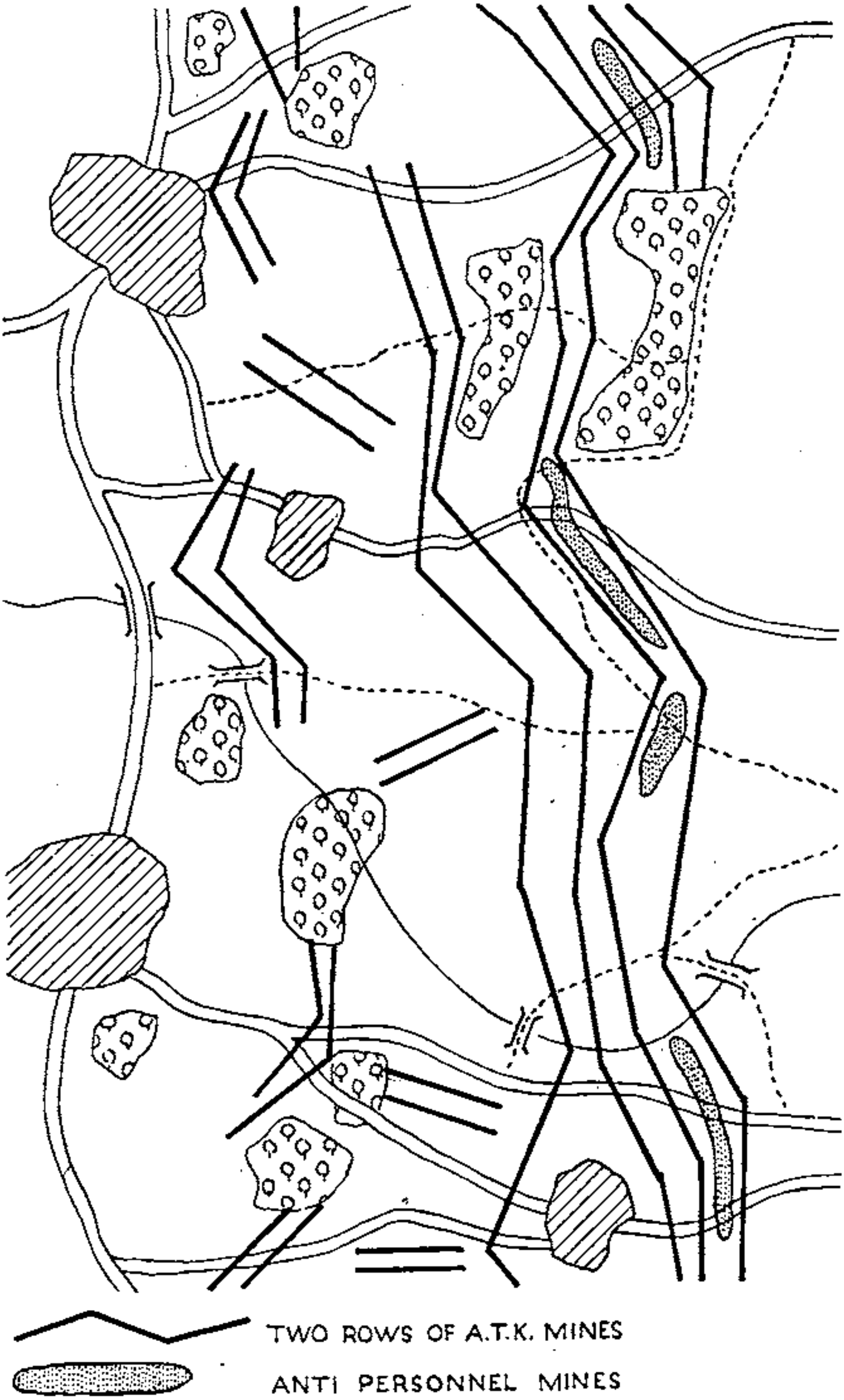
This plan maintained the over-all depth, it increased the number of rows in the forward belt and put the anti-personnel mines within these rows. More attention was paid to thickening up wire fences within the field. In the first plan all the wiring effort had been used locally near the defence positions.

There was still a continuous belt of mines across the front, although the rear part of the field had been weakened to provide the extra rows in the front edge. Lateral movement had been restricted by a few rows running at right angles to the main direction of the field. These also had been provided at the expense of the rear rows, as the total number of mines available was limited.

The duty officer hoped that by increasing the forward rows, the chances of a mine being overlooked were greater, as there would be more mines to lift to make a gap. Also he hoped there would be such a high rate of casualties among the "lifters," caused by artillery fire and by fire from the concealed positions in the field, that this method of breaching could not be sustained.

The duty officer looked at his sketch. He did not feel altogether satisfied with it. He even wondered if it was really any improvement. He had dreamed of the enemy attacking in one way. If he attacked in another—a large armoured rush on a very broad front in an attempt to outflank and get behind the main position, for example, the first method would probably be better. He wondered . . . the air in the L.C.V. was heavy again. The signallers remained watchful but silent behind their glass partition.

SKETCH 2



NOT TO SCALE

The Second Attack

The duty officer from his O.P. looked again over the terrain in front of him. He did not envy the infantry men concealed well forward in the minefield. Their positions had been so well camouflaged that even through binoculars it was quite impossible to see them. From where he stood he could see a single track running away from him across a ploughed field. He presumed the tracks must have been made by a party which had laid one of the subsidiary minefields designed to stop lateral movement in the area.

The enemy attacked in the late afternoon. The enemy had not discovered the full extent of the field and the first wave was made up of tanks alone. These advanced in groups of three on about a 1,000-yard front. But the field was too thick and it was not long before every one of them had run on to a mine. A result which even the most hopeful mathematician could scarcely have expected. But the duty officer noticed that some had advanced well into the field and had not succumbed until they had reached the seventh or eighth row.

It was not long before the next wave appeared. This followed the familiar pattern with two men prodding in front of each tank. In its turn this attack was stopped. Small arms fire from the positions within the field (the main positions were again locally neutralized by intense artillery fire—H.E. and smoke) and our own D.F. tasks had achieved their purpose. The casualties among the men outside the tanks were prohibitive, and despite the prodding, many tanks went up on mines which had been overlooked. The men on foot were obviously and understandably incapable of finding mines accurately when under artillery and small arms fire. So far so good—the enemy withdrew.

An Active Night

That night there was active patrolling on both sides. It was feared that the enemy would start breaching, but our patrols found no sign of this happening. The duty officer himself went out with a party to blow up one of the disabled enemy tanks.

About one hour before dawn enemy aircraft were heard. Soon after, about a dozen fighter-bombers flew overhead, but their aim was poor and all their bombs except for a very few fell in the minefield, and even the ones that did fall near the defenders did no damage. As dawn came there was the sound of enemy tanks, presumably forming up to attack once again.

When there was enough light to see, the battlefield looked much the same. Only the newly-turned earth around the bomb craters, which stretched in a pattern across the field, was noticeably different. Then suddenly the scene changed.

A star shell was fired high up into the air. At this signal, each bomb crater disgorged about fifteen men. These men crawled away quickly and disposed themselves flat on their stomachs in a long line stretching back towards the enemy positions. At the same time enemy tanks accompanied by their prodders appeared.

Casualties No Object

The plan was soon evident. Just before dawn when our own patrols were likely to be returning to base, several lanes had been marked out with green tape pinned to the ground. At the same time the enemy had occupied each crater made by the bombers. At a given signal, these men had rushed to where the tapes were laid so that there was about one man per 20 yards in each lane. They then had the task of clearing their 20 yards of mines.

The craters also served another and more damaging purpose. Besides providing shelter for reinforcements for those killed in the lanes, they provided shelter for machine-gun posts and riflemen whose task it was to neutralize the defensive posts within the minefields. The prodders were therefore able to survive longer.

The gaps were made. The tanks again took up hull-down positions and their fire enabled the infantry who were following up to get through. But this time the lateral minefields took their toll. The number of enemy tanks disabled and the numbers of enemy killed while clearing the lanes were very high. Indeed so high that the duty officer from his O.P. wondered if the enemy would be able to hold out against the counter attack he knew would come.

" Wake up, George. Some duty officer you are ! "

The duty officer looked up guiltily. His relief had arrived. Thoughtfully he walked off to wash and shave before having breakfast.

Depth and Delay

As he shaved he thought over this second attack. His dreams had been so vivid that he felt weak and tired. Two attacks in one night were more than he ordinarily bargained for. But one or two points became clear to him. He tabulated them in his mind so that he could make out a new plan directly he went on duty again. His points went like this.

The accent so far had been on the following :—

(*a*) Making a continuous belt of 800 yards or so in depth over the whole front.

(*b*) Two mines per yard of front had been accepted as the desirable maximum density.

(*c*) Depth had been decreed as being necessary so that the enemy could not breach in one night.

He thought over these points, especially the last one. Was depth as such really the factor that caused most delay to a breaching party?

To his mind delay was caused by the following, in order of importance:—

(1) The degree of opposition, i.e.—
small arms fire,
artillery fire,
anti-personnel mines,
obstacles such as wire.

(2) The extent to which the mines were detectable to either detectors or the eye.

(3) The number of mines which had to be removed to make a lane.

(4) The extent to which individual mines were booby trapped.

(5) Depth, i.e., the distance which a breaching party actually had to walk. This clearly should be of the order of hundreds of yards, but it was not the most important factor in itself. In fact, within reason, depth seemed the least important.

How then could these factors best be made use of, especially if the enemy did not mind if he lost considerable numbers while breaching?

The Third Plan

On returning to the L.C.V. he drew up another plan (Sketch 3).

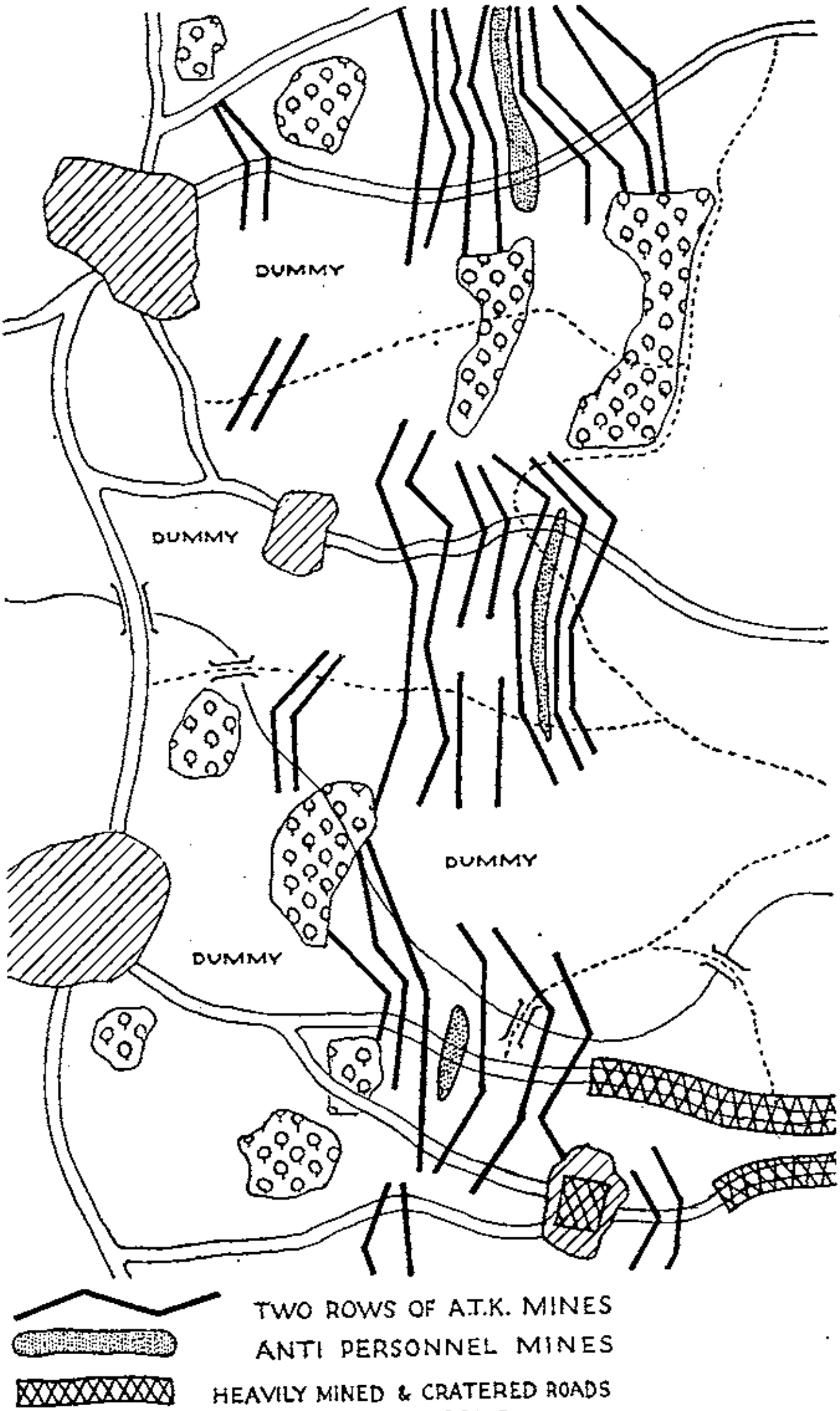
He had noticed that in both previous attacks the main thrusts had been made in approximately the same places. The attacking columns of tanks and infantry had obviously been using existing roads and tracks as their centre lines. This both facilitated control—keeping direction—and was also logical in that the tanks and troop-carrying vehicles had clearly been advancing along these routes until forced to deploy. They had then deployed astride them. His first point then was that all the main roads and tracks should be well and truly blocked.

He considered that at least twelve to sixteen rows stretching in one belt about 300 to 400 yards deep and about 1,000 to 1,200 yards wide should be placed astride each route.

Defences, some within or very close to the belt, must be sited to cover these rows with small arms fire. D.F. tasks must fall on their front edges.

As the number of mines available and time for laying were limited, the gaps between these thick belts should be covered with small subsidiary belts only—about four rows each. Areas where attack seemed unlikely should be neglected—the mines previously used in them should be used to thicken up the more important belts.

SKETCH 3



NOT TO SCALE

(After all, thought the duty officer, no one considers spreading the defending infantry all along the front. Why then spread the mines evenly throughout the area?)

All available anti-personnel mines were to be laid within these dense belts. Low wire fences were also to be erected, especially in any folds in the ground, in which a man lying was protected from the defenders machine-gun fire.

The duty officer looked at his sketch. He did not altogether like it. Leaving thinly mined gaps was a risk. Obviously these gaps must be kept under observation and the mobile anti-tank guns must have previously prepared positions from which to cover them.

The duty officer chewed his pencil. Was there any other way in which the enemy could be encouraged to attack where the minefields were strongest? Three ways occurred to him.

(*a*) The mines must be camouflaged. If the dense areas were too obvious, the enemy would avoid them. Also if well concealed the mines would be more difficult to pick up.

(*b*) Dummy minefields should be laid in the thinly-mined areas to give the illusion of the same strength all along the front. These might be neglected—as before—but used like this they would be worth while.

(*c*) Some roads and tracks should be more heavily mined and cratered for some distance—three or four miles—in front of the minefield than others. This might encourage the enemy to use the less heavily damaged ones—and consequently to run into the more heavily mined areas of the main field. The field should be laid out accordingly.

The duty officer's mind ran on. More booby traps to prevent mines being lifted. More wire. More trip flares. More . . . He brought himself back to his sketch with a jerk. Perhaps, after all, the more straightforward layout (Sketch 1) was the best all-round answer. He wondered if the station-master at Hamm had been so lucky after all. He must have got tired of being for ever thinking out new and better plans. Perhaps he too went on improving and improving until he suddenly found himself doing what he originally started with.

The duty officer sighed. He tore up his sketches. One thing at a time anyway—they still had not finished working on the first plan.

"THE WERAGAMTOTA BRIDGE"

By CAPTAIN J. J. KILLELEA, R.E.

IN the heart of Ceylon lies the province of Uva, noted for its heat, jungle animals and wild men, for it is here that the Veddahs dwell, still primitive and complete with their bows and arrows, long hair and deer-skin clothing. Their villages are located near the Horabora Wewa tank, on the east side of the fast-flowing Mahaweli Ganga, which takes the monsoon flood waters from the hills down to Koddiyar Bay near the great naval base of Trincomalee.

In 1949 a broken-down old Buddhist temple near the village of Alutnuwara caused religious excitement throughout the length and breadth of Ceylon on account of a declaration made by the high priests of the "Temple of the Tooth" in Kandy, that Lord Buddha rested at this temple during his visit to the country in the third century B.C.

The Ceylon newspapers gave this important declaration its front pages, and soon the Singhalese, loving all forms of religious ceremony, were clamouring for the Government to arrange some form of communication to the temple, as the only road that existed to take them any way near the place was to the village of Weragamtota on the west bank of the Mahaweli Ganga; and here only a small ferry existed, just capable of carrying four people across the 1,000 ft. wide river, and, due to the fast flow, it took forty-five minutes to do the return journey.

About this time the religious leaders decided to raise funds for the purpose of building a replica of the temple over the existing one, in order to preserve it for all time, and from their almanac, decided that the most suitable time for a pilgrimage would be on the 15th and 16th August. This left about three weeks for some form of bridge to be built across the river, the most difficult time of the year, as the forerunner of the monsoon had already hit the hills.

The papers were full of criticism, blaming the Government for lack of action, and reminding the public that there were only three weeks to go. Within a few days, the Prime Minister, Mr. D. S. Senanayake, had summoned his works minister, Sir John Kotilawella, and P.W.D. experts, and the press continued to publish reports on these conferences which daily showed no progress; in short, the P.W.D. stated that the task could not be undertaken in so short a time, and to build even a temporary structure would take at least three months. I had followed the newspaper reports with mild interest, little knowing that in the course of the next few weeks I would literally be up to my neck in it, remembering it for the rest of my life.

Whilst all this excitement was going on, the British Military Garrison in Colombo was in its second phase of the rundown, and great headway had been made in reducing the strength of the various units there ; the Royal Engineers had been reduced to three officers, a few British other ranks and key civilian personnel. The officers were Major H. Harvey-Williams, D.C.R.E., Captain W. L. G. Hammett, Garrison Engineer, Colombo and myself A/D.C.R.E.

Well, to begin my story of the bridge ! It appears that the Garrison Commander, Brigadier F. S. Reid, C.B.E., had called in the D.C.R.E. and asked if there was anything that the Royal Engineers could do to assist the Prime Minister in getting these many thousands of pilgrims across the river. He and Hammett, therefore, set off to reconnoitre the Weragamtota approach ; the journey involved a distance of about 200 miles from Colombo and back, and the last thirty miles from Kandy to the river included twenty-five acute hairpin bends and a drop of some 4,500 feet. During the journey back, Hammett conceived the idea that a series of floating rafts was worth further consideration. The main snag was the continuous rise and fall in the water level from anything up to fifteen feet. However, upon their return, I was brought into the picture and after going into the pros and cons of the situation, the Garrison Commander was informed that we would attempt to connect a series of rafts across the river subject to availability of stores and labour. He in turn informed the Prime Minister and from then on things began to move rapidly. All red tape was thrown to the wind and the co-operation all round was quite unbelievable.

There was just one week to go now, and Major Harvey-Williams was given instructions to deal direct with the civil authorities, which he did immediately by attending a high-level conference, the outcome of which gave him the power to recruit local labour at the bridge site, deal direct with various Government departments for stores, and on behalf of the P.M., co-opt the British Government agent of the province who had wide administrative powers.

H.W. from now on undertook all administrative matters, leaving Hammett and myself the task of building the bridge, so we proceeded to draw up our plans and stores lists. Hammett and I had a small Austin staff car at our disposal and a 15-cwt. lorry. The latter we loaded up with selected stores from the now very limited supply at the G.E.'s yard at Colombo such as axes, crowbars, hurricane lamps and S.W.R. We had decided at about this stage that we would build rafts on a mass production basis, consisting of three piers of five 45-gallon oil drums, each supported top and bottom by timber runners and held tightly to the oil drums by binding wire windlassed between each drum, the timber being grooved on each runner to prevent slipping. The piers would then be placed in three rows parallel to each other and 3 ft. apart. Road bearers were then to be placed horizontal to the runners, five in number and square-lashed with binding wire at alternative timber crossings, timber decking, and end ribbons snake-lashed along the outside bearers. The method of joining the rafts together, and anchorage, we decided to leave until we could try by trial and error, although we agreed in principle that an overhead anchorage might be the answer. The rest of the design we decided to improvise as we progressed.

H.W. had arranged for 700 empty water-tight diesel oil drums to be moved to the site by road, from Galle, 100 miles from Colombo, and over 200 miles from Weragamtota. Arrangements had also been made with the land development authorities at Minipe for their saw mills to cut timber to our sizes on demand, so things at this stage seemed encouraging.

Six days to go now, and our next move was to the Government rest house at the village of Weragamtota, which had been placed at our disposal by the P.M. himself. So, with the best wishes of the Ceylon Press, in the morning papers, we set forth, arriving at the rest house in the late afternoon.

The last stage of the journey from Kandy was trying, but a glass of cold beer from the paraffin refrigerator made things all right again. On the Kandy road we had noticed great preparations under way ; the Police had installed a wireless station at the top and bottom of the 30-mile pass, to control the traffic up and down ; banners and slogans were everywhere ; realizing who we were as our small retinue passed, buddhist priests in their yellow robes, fans, and bald heads, bowed reverently.

After dumping our kit, and the glass of beer I spoke of, we moved over to the proposed west bank site already earmarked by Hammett on his previous visit, and as it appeared as good as any, decided to unload the stores. Whilst this was in progress, Hammett and I walked down to the water level. The bank was quite steep and a local villager who tacked on to us here explained that two days ago the water was within two feet of the top and if it rained in Badulla to-night, the flood water could be expected at this point in nine hours. This indeed was a piece of valuable information and we thanked the informer accordingly.

Shades of night were now upon us and we returned to the rest house, only to find chaos when we arrived, as H.W. was sitting at a table on the verandah of the rest house surrounded by hundreds of villagers, all clamouring to be taken on as labour. Those selected were given a piece of paper bearing H.W.'s elaborate signature and told to present it at the west bridge site at six o'clock in the morning, also not to lose the paper, as this was the only way in which payment could be made.

A few headmen were selected as Kanganies, to boss the various gangs, and after getting police reinforcements to clear away the onlookers, we settled down for the night—but not for long as, over the water from the temple area, drums started their monotonous rhythm which was to continue every night while we were there, steadily increasing in tempo and only stopping with the light of dawn.

Five days to go now and our task not yet started. Up at dawn, a cold shower, and Hammett and myself, after a breakfast of eggs and cheese (as that was all the rest house keeper had) boarded the truck and moved off to the west bank site. Here we found Don Victor our Stores Superintendent from Colombo, recording the labour, dividing them into works parties and selecting brighter individuals for more important tasks.

At 0060 hrs., the first lorries started to arrive with the oil drums from Galle. Poor drivers! I felt really proud to see them. Two hundred miles of twisting narrow roads is no joke, especially at night, but I suppose they were to an extent religiously inspired. Soon the stores were piling in from all over Ceylon. Hundreds of oil drums, picks and shovels, heavy bulk timber, rope, nails, etc.

This start was most encouraging. We forgot about lunch and satisfied our thirst with "Karumbas" or king coco-nuts, and about midday we were ready to start, I and a gang of about twenty Singhalese and Tamils moved over to the east bank in a small canoe ferry, four at a time, and started on the east approach. After sighting the centre of the bridge, we cut the undergrowth and transformed the steep slope into a more gradual incline. The water level was reasonably low and six elephants loaned by a timber merchant carried timber and stores across the river to us, all day long.

After clearing the approach, I called over to the west bank to see how Hammett was progressing. There I saw a hive of industry: barrel piers being turned out like "L" ships (Photo 1). During the war, Hammett had given a practical demonstration and the village carpenters had followed suit. I returned to the east bank with ten carpenters who had answered the call, and began to build trestle seats, the idea being to trestle down to the level of the rafts, the east bank being much steeper than the west. By nightfall I had trestled out about twenty-five feet, and decked down (Photo 2). Water being down, these trestles though heavy could be moved into position quite easily. Hammett had completed about fifty piers and was ready to build and float his first raft at daybreak. Back to the rest house and to two bottles of iced beer that never touched the sides!

H.W. had returned to Colombo, to get tally discs, food, and to have a bolt coupling manufactured which we had designed to connect the rafts together. After our eggs and cheese, Hammett and

Photo 1.—Barrel rafts.

Photo 2.—Trestle piers

Photo 3.—Launching of barrel pier.

The Weragamtota bridge 1,2,3

Photo 4.—Barrel rafts forming bridge.

Photo 5.—Bridge nearly complete.

Photo 6.—Pilgrims crossing the bridge.

The Weragamtota bridge 4,5,6

I sat down to talk over our day's work and to complete the bridge design. We decided to anchor our rafts on to an up-stream floating boom, 3-in. S.W.R. suspended above water level on three rafts ; the first ten rafts could be anchored to the bank. Our main worry all the time being the threat of high water, the G.A. had arranged for the Badulla police to inform us if heavy rain fell in the hills. In anticipation of a high rise in the water level we designed a greased ramp for the west bank to enable the shore bay to rise and fall and still maintain dry contact. Local cart axle grease eventually did the trick and so, quite pleased with things generally, except for the drums, we slept the sleep of exhaustion.

Four days to go ! Oil drums were still arriving, and while Hammett paid a visit to the saw mill some ten miles away, I returned to the east bank and prepared more trestles, road bearers, decking, as we had already agreed that in the event of insufficient drums arriving I would have to trestle out to meet the rafts. I had one labour gang cutting through the jungle to a cart track that led to the temple about three-quarters of a mile away, while my other labour gang assisted the carpenters with the trestles. By midday, I was out 50 ft., decked down with hand-rails. I returned to the west bank where Hammett had given his demonstration of raft building and the first one was in the process of being launched down a prepared bank slope, down stream (Photo 3). We both realised that this would have been better up stream, but the nature of the bank prevented it. This was most regrettable as we had great difficulty later on in floating the rafts in to bridge, as it lengthened and the flow of the river increased. While I concentrated on the bank seat and sliding ramp, Hammett went speedily ahead with raft building and by 1400 hrs. five were completed, in the water, and ready to go in to bridge. By 1500 hrs. ten rafts were in bridge and anchored to the shore (Photo 4). By 1800 hrs. we were 200 ft. out.

At about this time we both went over to the other bank, a shorter distance now for the ferry man, and, as we approached, we saw on the trestle pier about a dozen Veddahs armed with their bows, taking great interest in the proceedings. We shook hands about ten times all round as they love this form of greeting, and through an interpreter we were asked if they, too, could work on the bridge. We said that they could. The oldest one said that they would work until it was completed and for payment they asked for a hand axe that they saw our men using. At first we thought that they wanted one each, but it transpired that one for their village would be sufficient, so they signed on as Veddah No. 1 and so on. I asked the old man if he would let me use his bow and arrows and after I had hit a tree some fifty feet away, they were delighted, and night being near, we told them to report in the morning and returned to the rest house.

At about 0030 hrs., there was a knocking at the window and opening up we saw a Ceylon police motor cyclist who said that he had come all the way from Badulla as radio communications had broken down, with a message from the A.S.P. to the effect that heavy rain had started in the hills and that we must expect high water about midday. We gave the policeman a cup of tea and a shake-down for the rest of the night and discussed the situation generally. We came to the conclusion that the boom anchorage must be put across first thing with all possible speed. Sleep was now impossible so we dressed, made some tea and moved down to the bridge. It was about 0050 hrs. now and only three days to go. The river had risen about four to five feet already and was on the move much quicker, about five knots.

As soon as sufficient general labour arrived we sent for the ferry man, who had sent a message to the effect that he was not going to help any longer. He had suddenly realized that he was helping to do himself no good, as, once the bridge was built, no one would use his ferry. We took the law into our own hands in the end, however, and took his little but valuable ferry by force, agreeing on behalf of the Ceylon Government to pay him reasonable compensation.

First we had to get a 3-in. rope across the river to assist us in getting the steel wire across. This was a task in itself; men wading out in the river were washed off their feet and Hammett and I were becoming worried; every man had a rope tied to his waist and the other end was fastened to the raft we were poling out to midstream. In time, with lots of shouting, driving and promising we succeeded in getting the rope, after many joins, across to the other side, and three rafts moored to it, at intervals of about 350 feet. Storm clouds were gathering as we started to haul across the S.W.R. and many is the strange swear word that must still be ringing throughout the jungle. I must have raved like a lunatic in driving the villagers to put every ounce of strength they had into the job.

Once that steel rope was in the water it must have weighed tons, and on one skimpy meal a day it must have been agony for those in the water up to their necks, as wet hands and a thick steel wire rope were never the best of friends. During all this commotion, I fell off the top trestle. In an endeavour to fall clear of an old man I fell awkwardly and heard a sharp snap as if my ankle had been snapped clean off. I felt an agonizing pain, but at that moment the cable we had just managed to get to the other side of the stream slipped and the centre was already looping out about 400 feet down stream. I recall running to the top of the bank and by pure savagery compelled the exhausted labourers to hold fast. After a terrific struggle we held it, but it took two elephants and 150 men to pull it in, until it rested near enough on the water. On my side I directed by actions, broken English and a few words of Singhalese thrown in, how I wanted the earth anchor done. The pits had already been dug, and after a while the S.W.R. was wound around a spar, bull-dozed and buried. My ankle had swollen beyond recognition and I was carried back to the bridge approach. Hammett came across and said that I had better get to Kandy straight away. The ankle looked dreadful and the pain was unbearable. My *kangany* came up to me and asked if the native doctor could have a look at my foot as the native doctors were expert in dealing with breaks and sprains. I consented. I would have consented to anything to relieve the pain. The native doctor came from the temple area, looked my foot over like an expert, gave my toes a sudden jerk, until I thought he had pulled them off, grunted now and again with satisfaction and finally applied an evil-smelling concoction, saying he would call again at the rest house in the evening. I decided to stay on at the bridge and a gang of strong-armed fellows carried me on a plank everywhere I wanted to go.

On the west bank, with the help of a tackle we managed to tighten the S.W.R. and make fast the end and eventually secure the boom rafts. The water had now risen about eight to nine feet, and the flow had increased to about seven knots. More rafts had been brought in to bridge and on the west bank we were out about 600 feet. Connecting the anchor guys to the boom was another difficult problem and at times heart breaking. By about 1700 hrs. the water had risen alarmingly and things did not look at all bright. We continued to build.

At about 1800 hrs. a deputation of priests in their yellow robes came from the temple and asked if they could put a charm on the bridge. To please them, we said that they could go ahead and a simple ceremony was performed in which a stick was lashed to the side of the trestles, just touching the surface of the water. We learned afterwards that all those working on the bridge had promised to contribute towards a silver replica of the bridge, about six inches long if the charm worked and the water subsided before the great day.

That night a watch was put on the bridge, as large tree trunks were being washed down with the flood waters and fouling the rafts. We returned to the rest house, weary, myself with a very painful foot. A doctor from the Ministry of Health was paying a visit to the area in connexion with sanitary arrangements for the pilgrimage. He heard of my accident and came to the rest house to see me. He thought that I had better go straight off to Kandy to be X-rayed, but I felt that the foot could wait until the bridge was finished. After he had gone my native doctor came out of the darkness and did all sorts of queer things, finally covering my foot with a green slimy paste that consisted of roots, the guts of a snake and arrack. He told me that I would be walking inside three days which was unbelievable as my foot was three times its normal size with green and yellow bruise marks nearly up to the knee. Next day it did feel much easier and I began to have great faith in this evil-looking fellow, whose left eye seemed to be in the middle of his cheek.

Two days to go! Water still high and sufficient drums only for another 400 feet. We decided, therefore to try and extend the trestles as far out as possible. This was a most difficult task as, owing to the depth of water, I had to launch the trestles over the end of the pier and, as the bottom mud sill touched the water it tended to be washed down stream as its weight was insufficient for the pressure of water. But manage we did, and by nightfall we were 200 ft. out, with the water showing no sign of going down and lapping angrily at the chesses. (Photo 5).

More oil drums arrived and we concentrated on raft building at night by the light of flares, and by midnight we were ready to complete the bridge in the morning, providing the floating part was not washed away by then. We had very many narrow escapes, but when the dawn came it was still there. One day to go and by 1000 hrs. a wireless message had been flashed to the P.M. that the bridge was complete. Colombo radio broadcast this news hourly, and newspaper reporters were arriving in bus loads. The rest of the day we spent in making the bridge pretty. In the centre of the bridge we attached a double raft for use by the police in traffic control. A lighting set had been sent by the P.W.D. and the electricians lit up the bridge in coloured lights. Road approaches were then made presentable and by 1700 hrs. everything was ready.

During the night the charm worked, to our regret, as, when the water subsided we found that we had too much bridge. However, it served its purpose and the police estimated that 500,000 pilgrims crossed in two days (Photo 6).

The Prime Minister arrived at about 1000 hrs. and spoke over a loudspeaker system to the great multitude, most of it full of praise for the British in helping out and completing the bridge in four and a half days with untrained labour. This speech was repeated many times in the press.

After a month it was decided that the bridge was to be dismantled, stored in its component parts and used again in 1951. We know it was eventually stored on a site near Weragamtota, but whether used again we do not know. For my part, I was walking about within a week and, to my own surprise, running in ten days. The Veddahs gave me the bow and arrows that I had used and a pleasant letter from the Prime Minister and General Sir John Crocker, C.-in-C., M.E.L.F., made it a happy memory for all of us.

THE LAST HOURS OF NORTON HALL

By Lieut.-Colonel F. H. Lowman, D.S.O., M.B.E., R.E.

Introduction

IN December, 1951, 131 Airborne Engineer Regiment, T.A. was offered the opportunity of demolishing the remaining shell of Norton Hall, a large manor house near Daventry, whose owners once farmed the spacious lands of Norton Park.

The original part of the building dated back to the early sixteenth century, but early in the nineteenth century a gentleman by the name of Beriah Botfield acquired the property and felt moved to have a large and not very pleasing house built. This incorporated the original structure and embodied the towers and artificial battlements considered so necessary at that time to merit the title of a Hall. After various changes of ownership it was finally condemned to demolition after the second World War and Norton Park split up into small-holdings.

The demolition contractors failed to complete their task, or possibly found it more convenient to do so, and T.A. Airborne Sappers were only too ready to accept the offer of some practical demolition training and bring down the remaining shell, so that the owner could convert the site into a stock farm.

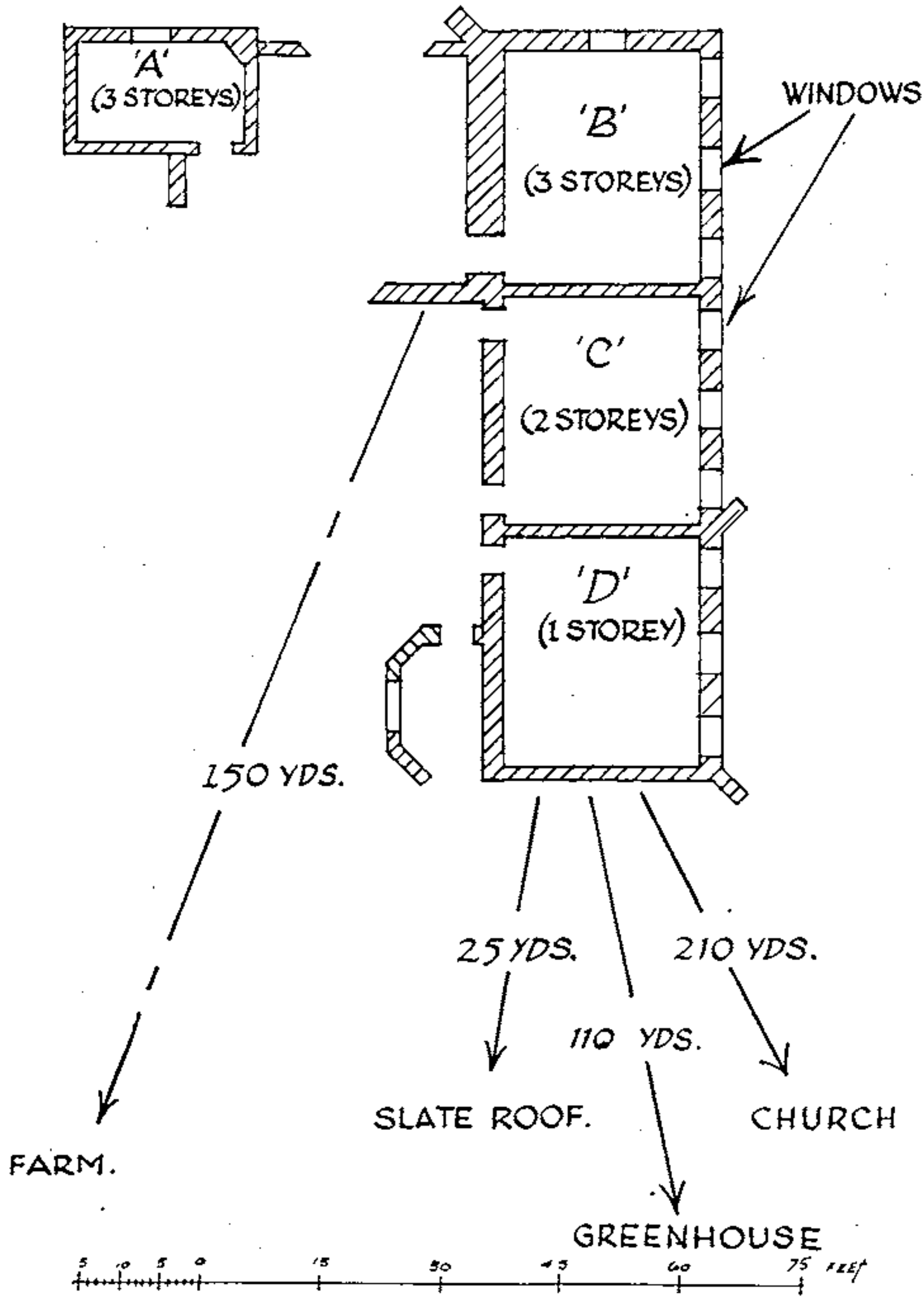
Preparations

The site was reconnoitred in January under very adverse conditions. A bitter east wind and lashing rain that drove through the many openings in the shell numbed the fingers and made even a rough sketch an ordeal. The difficulties were increased by the fact that many of the walls were still covered with lath and plaster which made it hard to determine their actual thickness and composition. However, in spite of the elements, sufficient data was noted from which to prepare a fairly detailed scheme.

To ensure a minimum of damage to neighbouring property on the restricted site, notes on the structure and the detailed proposals for its demolition were submitted to the Technical Services Department of Messrs. I.C.I. (Explosives) Ltd., who kindly offered to comment and advise on them. Mr. Hancock, whose name will be known doubtless to former demolition instructors at the S.M.E., agreed the proposals with one minor exception and added some very useful and practical advice on certain aspects of the task.

It was hoped that the way was now clear to carry out the task as a week-end training exercise at the end of March, but a quite unexpected difficulty arose in the form of a new A.C.I., laying down the conditions to be satisfied before R.E. could undertake such work for civilians. An opinion expressed in one authoritative quarter that this particular A.C.I. was intended to simplify the procedure in

NORTON HALL SITE PLAN



such cases was found to be unduly optimistic, and it was only after much writing and even more telephoning that verbal approval was obtained forty-eight hours before the T.A. Sappers had to concentrate in the Midlands from Croydon, Hendon and Hull.

The Site and Structure

A site plan showing the remains of Norton Hall in relationship to neighbouring buildings is shown opposite. From this it can be seen that various buildings susceptible to damage, particularly by blast, lay within 100 to 250 yards of the target. A low wall ran on three sides of the shell, and only 10 yds. from its base, and is shown in the photograph. The Sappers were asked to avoid damage to this wall and scattering of debris beyond it if possible. As the shell rose to three storeys, some sixty feet high in places, one measure of final success was taken as the satisfaction of this request.

Details of the structure itself are given on the site plan and appendix attached. It was known that the North Tower, designated Block " A," was of sandstone. Block " B–C–D " was originally thought to be of stonefaced brickwork, from such portions as were bared, and it was only after drilling had started that the North Wall at " B " was found to be very old masonry with rubble filling, obviously part of the original building.

Method of Demolition

In view of the restricted nature of the site the only possible method appeared to be accurately calculated and balanced borehole charges. Contrary to normal service practice it was decided that all boreholes should dip at 30 deg. to the horizontal to obtain the maximum disruptive effect against a free face ; this decision was strongly supported by I.C.I. The bulk explosive available was Plastic 808 and, again contrary to normal practice, each borehole charge was to be initiated by one guncotton primer and one lead of Cordtex ; this was necessary because of the total number of boreholes and the limited training allotment in explosive accessories.

In order to keep down the total charge fired at any one time and yet to complete the whole task within the two working days available the demolition was divided into three stages :—

Stage I—Block " A."
Stage II—Block " B–C–D," south and east walls and internal partition walls.
Stage III—Block " B–C–D," north and west walls, external bow window and partition walls.

Block " A " was selected for firing first as it was the smallest total charge and would indicate the general blast effect. The north and west walls were left until last to provide blast protection on the side where damage might result to neighbouring property.

The basis of calculation for all borehole charges was :—

$$W = 2\ L^3 \text{ oz. (L being half wall thickness in feet)}$$

This formula is only discernible to the most persevering student of demolitions after peeling off several layers of amendments in M.E. Volume IV.

However, it was considered advisable to double the basic charges, up to 2 and 4 oz. respectively for 18- and 24-in. walls. Furthermore, the basic charges in all buttresses and the boreholes nearest any corner were again doubled.

Two rows of staggered boreholes were used throughout, the spacing being based partly on M.E. Volume IV and partly on what fortunately proved intelligent guesswork. The bottom row was sited as close to ground level as was convenient for drilling and the greatest height of any top row was about four feet. The length of all boreholes was accurately calculated to centre the charge in each wall. Details of borehole charges and their spacings are given in the attached appendix.

Execution

Three lightweight Airborne compressors mounted on 10-cwt. trailers were used, operating one rock drill each, and ran with practically no trouble at all throughout the whole task. All boreholes were drilled $1\frac{3}{4}$ in. diameter, except for those in the north wall of Block " B–C–D " at " B " which were 2 in., decreasing to $1\frac{3}{4}$ in. All holes were drilled from inside the building for Stages I and II, as I.C.I. suggested this would encourage the walls to collapse inwards. For Stage III they had of necessity to be drilled from outside to permit charging after the debris of Stage II was down.

Drilling, charging and firing of Stage I were completed first. All boreholes for both Stages II and III were drilled next in case vibration from drilling should cause any collapse of the remaining north wall after Stage II had been fired. In the case of Block " A " the rate of drilling achieved in the sandstone was nearly twice that given in R.E.S.P.B. Pamphlet No. 4, and slightly faster than the quoted figure for the sounder brickwork in Block " B–C–D." The north wall of " B–C–D " at " B " gave some trouble, however, owing to the loose nature of the old masonry which kept on falling down and clogging the drills. No difficulty was experienced in drilling, clearing or charging the sloping boreholes apart from this.

Some 350 boreholes in all were drilled, ranging from twelve to thirty inches in length and the charges varied from two to sixteen ounces according to their position and the thickness of the wall concerned. Cordtex leads from the borehole charges were brought into junction boxes in groups of five or six and these junction boxes in turn connected to the ring main.

Photo 1.—The shell of Norton Hall from the south-east—block "A" on the right.

Photo 2.—Blocks "B", "C", "D" coming down.

The Last hours of Norton Hall 1,2

Photo 3.—Blocks "B", "C", "D" after Stage II.

Photo 4.—After Stages I, II and III.

The Last hours of Norton Hall 3,4

To minimize the risk of damage to near-by property through flying masonry, sloping aprons were propped against the external faces of the walls concerned covering the estimated area of ruption. Sections of lath and plaster available provided convenient material for these aprons.

Results

Stage I, Block "A," was fired just before lunch-time on the Saturday and in spite of being the smallest total charge, with only 9½ lb. of bulk explosive, was the most impressive of the three. A puff of smoke and dust ringed the base of the tower and was followed by the noise of quite a modest explosion, but no blast. The tower quivered for a moment and then with a rumble it subsided on its base slowly and deliberately, the sections of the tall chimney stack settling on top of the debris as if loth to leave their accustomed positions. Inspection revealed that the tower had collapsed vertically on itself and the low perimeter wall remained intact, with only one small piece of masonry beyond it.

The firing of Stage II, with its 36½ lb. of bulk explosive, produced a noticeably louder explosion and a little blast but no flying pieces of masonry. As the north wall of Block "B–C–D" had deliberately still been left standing there was a natural tendency for the debris to slide out at the base and one coping stone on the low perimeter wall was dislodged.

Stage III contained 49 lb. of bulk explosive and, therefore, produced a correspondingly louder explosion, but rather strangely considerably more blast than Stage II. The demolition, however, was unfortunately not quite complete. A portion of the north wall at "B," which must have been a skin not bonded to the original structure, had tilted out as a result of Stage II to rest against some cast iron beams that had come down in a nearly vertical position. As this remaining portion of wall might constitute a danger to children playing amongst the ruins, its demolition was completed by a more primitive method in the form of a heavy timber baulk handled as a battering ram. This last incident aroused much amusement amongst onlookers from the village near by.

A final inspection of property in the neighbourhood unfortunately revealed two small holes and three or four cracks in the east window of Norton Church, just over 200 yards from the target. Luckily the damage was confined to those sections of the stained glass which could more easily be replaced. This was obviously atributable to the blast from Stage III. Apart from this the only damage was to some windows in a cattle shed near by which were expected to go, the collapse of a small section of plaster ceiling in a storeroom and one coping stone on the parapet wall dislodged. Some fairly extensive greenhouses, only 110 yds. away, escaped unscathed.

The greatly increased blast from Stage III cannot be accounted for solely by the increased total charge and may well have been due to one or more of the following causes :—

(*a*) The older and looser masonry in the original part of the north wall of Block " B–C–D " and the resultant voids.

(*b*) The tamping effect of the debris resulting from Stage II and the tendency for ruption to occur on the open side nearest the other buildings and church.

(*c*) The use in the ring main of a civilian pattern double Cordtex, which there was not time to separate into a single strand.

Conclusions

There is a tendency to avoid drilling and using borehole charges for demolition if they can possibly be avoided. This exercise proved to all ranks that drilling, in homogeneous masonry at any rate, presents no problems, nor is it unduly slow compared with other methods. Likewise the drilling, clearing and charging of sloping boreholes raises no difficulties and greatly enhances the disruptive effect of the charge. Borehole charges provide admirable training, not only in the use of compressors but also for considerably larger numbers than with other types of demolition in the preparation of firing circuits and initiation of charges.

This week-end exercise provided 131 Airborne Engineer Regiment T.A. with not only valuable and popular training in demolitions, but also in administering themselves under field conditions and was quite obviously thoroughly enjoyed by all ranks.

APPENDIX

Details of Structure and Borehole Charges

Block	Part of Structure	Wall Thickness	Basic Charge	Hor'l Spacing	Vert'l Spacing	No. of Boreholes	Total Charge
" A "	Main tower	18 in.	2 oz.	18 in.	18 in.		
" A "	Ext. partition wall	18 in.	2 oz.	18 in.	18 in.	62	9½ lb.
" A "	Ext. partition wall	2 ft.	4 oz.	2 ft.	2 ft.		
" B–C–D "	East and south walls	2 ft.	4 oz.	2 ft.	2 ft.	148	36½ lb.
" B–C–D	Int'l partition walls	18 in.	2 oz.	18 in.	18 in.		
" B–C–D "	North wall at " B "	3 ft. 9 in.	16 oz.	3 ft.	2 ft. 6 in.		
" B–C–D "	North wall at " C " and " D "	2 ft.	4 oz.	2 ft.	2 ft.		
" B–C–D "	West wall	18 in.	2 oz.	18 in.	18 in.	142	49 lb.
" B–C–D "	Ext'l partition walls	18 in. –2 ft.	2–4 oz.	18 in. —2 ft.	18 in. —2 ft.		
" B–C–D "	Bow window	9 in.	2 oz.	18 in.	18 in.		
				Grand Totals		352	95 lb.

ROYAL ENGINEER WORK IN THE DEVON AND SOMERSET FLOOD DISASTER

By MAJOR D. E. THACKERAY, M.B.E., R.E.

THE widespread damage caused by the exceptional floods in Devon and Somerset during August of last year, provided another opportunity for the Army as a whole, and the Royal Engineers in particular, to demonstrate that with the limited resources now available in the U.K. much emergency aid can be provided to the civil power, provided clear forethought, a simple and flexible organization and intelligent improvisation are brought to the task.

The reason for these floods is now known to have been a unique rainfall on Exmoor which gave rise to excessive flood water in all rivers and water courses draining the area. As a result, the River Lynn and other streams were swollen to fast flowing torrents in the course of a very few hours. The effect of this phenomenon was felt most in the narrow gorge of the Lyn valley. Here the flood water, which carried with it an assortment of heavy debris, including boulders up to ten tons in weight, scarred and blasted for itself a passage in which complete bridges, houses and other structures were carried away. The major force of this was expended on the town of Lynmouth at the foot of the valley where the resultant damage was on an unprecedented scale. Elsewhere, the damage although less spectacular, was of considerable magnitude and extended over a wide area from Dulverton in Somerset, westward over the whole of Exmoor to the Barnstaple–Lynton road.

As soon as the implications of the disaster became known, immediate aid was provided by the Army, to assist in bringing order out of the chaos that resulted from the destruction of road and telephonic communications. Immediate assistance took the form of blankets, water carts, recovery vehicles and similar items required to alleviate the confusion and hardship caused by the disintegration of electricity, water and other public services, and by the virtual disappearance of complete houses, cars and other private property.

Such help was initially provided by A.W.X.E. at Fremington, and 264 (Scottish) Beach Brigade which was in camp at Braunton, near Barnstaple. The latter formation, also supplied Military Police to help in controlling the area which was at this time full of holiday makers, many of whom were stranded without accommodation. At an early stage, A.W.X.E. also began construction of a foot-bridge to link the island which had formed in the middle of Lynmouth with the mainland, and endeavoured to assist with DUKW's and other specialized equipment.

These immediate measures were continued until the 17th August, when a meeting was held in Lynton by the civilian authorities concerned, to assess offers of assistance and to decide the priority of emergency work now required. The Chief Engineer, South-Western District and other Army representatives including an officer from Chief Engineer's Branch, at Southern Command, were present at this meeting. After discussion with J. B. Carnegie, Esq., County Surveyor of Devon, it was decided that the immediate requirement was a bridge at Barbrook, south of Lynton, to re-establish road communication across the River Lyn. At the same time, as a result of reconnaissances made in Somerset, a second request for a replacement bridge near Winsford was accepted. It was evident that there would be other requirements as the situation became clearer, but these were the immediate tasks to be undertaken.

The Engineer troops nearest to the scene were Territorial units of which 121 Army Engineer Regiment of 27 Engineer Group and 102 Corps Engineer Regiment of 264 (Scottish) Beach Brigade were the major ones. The former had just arrived in camp at Penhale, near Newquay, and the latter at Braunton near Barnstaple. The Commanders of both these units were present at the meeting in Lynton and were thus fully in the picture from the outset. An immediate reconnaissance of the site at Barbrook showed that a certain amount of preliminary work would be required to prepare suitable bank seats for a Bailey bridge. The former bridge, a narrow stone-built one had been completely torn away from both abutments and the east one was still traversed by a large amount of surface and other drainage water. It was decided that this preparatory work would be done by the County Surveyor before bridging began, but that the bridging task would be given to 121 Army Engineer Regiment. The C.O. of the regiment, Lieut.-Colonel Horgan, T.D., and the Group Commander, Colonel Hutchinson, D.S.O., discussed this plan in detail with the County Surveyor on the morning of the 18th August, and bridging eventually began on the 22nd August. The site presented some difficulty owing to the narrowness of the gorge, but the bridge, a 90-ft. D.S. Standard Bailey bridge without ramps, was completed by midday on the 23rd August. An article describing this work was published in the *R.E. Journal* for December, 1952.

The second requirement for a bridge near Winsford was entrusted to 102 Corps Engineer Regiment. The Commander of this regiment, Lieut.-Colonel Muir, made a detailed reconnaissance on 18th August. As no civilian effort was required in connexion with this bridge, it was possible to get it constructed by the evening of 20th August, a very creditable performance by troops who were not fully trained in Bailey bridging. The bridge, a 50-ft. S.S. Standard Bailey bridge with ramps, was built over the existing gap in the centre of the former bridge.

Photo 1.—Night working in Lynmouth.

Photo 2.—Clearing the mouth of the estuary.

Royal Engineer Work In The Devon and Somerset Disaster 1,2

Photo 3.—The river estuary. An early stage in the building of the sea wall.

Photo 4.—Work on constructing the sea wall in an advanced stage.

Royal Engineer Work In The Devon and Somerset Disaster 3,4

102 Corps Engineer Regiment were subsequently called upon to build in succession a 110-ft. skeleton Bailey bridge at Dulverton, and a 90-ft. D.S. Standard Bailey bridge at Simonsbath. Both these tasks were tackled energetically and capably, with the result that the Dulverton bridge, which was required to carry sewage pipes and water mains, was built on the 22nd August, and the Simonsbath bridge by the 24th August.

On 19th August, a further bridging requirement at Hillsford, near Lynton, was notified, and as all Territorial units in the vicinity had been committed, it became necessary to call upon the nearest regular unit for this task. This unit was 32 Assault Engineer Regiment stationed at Tidworth. A reconnaissance of the site was made by the C.O. of the regiment, Lieut.-Colonel Barron, on 19th August, which showed that a 70-ft. bridge would be required with approximately seventy yards of approach work on one bank.

A composite squadron under the command of Major Gray was entrusted with this task. The unit moved to the site under regimental arrangements on 23rd August, and work on the approaches began with the help of plant on the 24th. Despite various difficulties and delays, this bridge was completed by 28th August, when it was opened by the Commander South-Western District, Major-General C. L. Firbank, C.B., D.S.O.

The nearest permanently stationed Territorial Engineer unit, 110 Field Engineer Regiment at Bath, also offered their services. They were given the task of constructing a 100-ft. suspension bridge at Tarr Steps near Dulverton. This they did as week-end training, completing the bridge on 31st August.

Although bridging was the first priority allotment of work, it was from the beginning of operations that much additional help could be given. The immediate opportunities for this were in the use of plant for the clearance of Lynmouth, and assistance to farmers in overcoming the many problems which confronted them. The widespread damage on Exmoor to fields, crops, fences, buildings and the like gave plenty of scope for all types of improvised aid. On 20th August, therefore, the Chief Engineer, South-Western District, formed a command post to co-ordinate all work of this description. This was established, under the command of Lieut.-Colonel Elkington, close to Blackmoor Gate on the main Barnstaple–Lynton road and was at once provided with telephone communications which proved of great value.

Apart from acting initially as a control post for all military traffic into Lynton, the eventual operations conducted from this post consisted mainly of assistance to farmers by means of manual labour under Royal Engineer control. A force for this purpose was supplied by various units in the area, including the Wessex Brigade Depot at

Exeter, and from R.E.M.E. and R.A.S.C. training units. This force grew considerably in numbers and at one time comprised upwards of 700. It subsequently set up a sub-H.Q. at Dulverton to control work on the east side of Exmoor. Plant for specific jobs was also attached, and amongst other jobs, helped with the rehabilitation of the Dulverton sewage works. Much valuable work was done by all ranks and considerable initiative was shown in improvisation and in tackling jobs, such as dry stone walling, which would normally be considered outside the capabilities of those who undertook them. It provided a fine example of the fact that where there is a will there is a way. The assistance given was greatly appreciated by the National Farmers Union, who were at pains to express their thanks to all concerned.

In Lymouth itself, some plant was moved in early to help with general clearance and allied problems. By 21st August, however, it was realized that if satisfactory arrangements for building up the sea wall against the September tides were to be accomplished in time, a much more intense effort would be required. Accordingly the complete Southern Command Plant Troop, under the command of Captain Ford, was moved to Lynmouth during the week-end 23rd–24th August. Extra plant was also brought in from Western Command and M.E.X.E. Arrangements were made for round-the-clock shift work, which was carried out at night by searchlights provided from L.A.A. Regiment sources. This proved most successful and was indeed a most spectacular sight, receiving the attention not only of the newspapers, but also of the newsreels, who took some impressive sequences!

To co-ordinate all work in the Lynton–Lynmouth area, Lieut.-Colonel Reynolds, O.B.E., of A.W.X.E. was installed in the temporary capacity of C.R.E. Lynmouth. Both he and the Chief Engineer, South-Western District, at this time set up their H.Q. in the Castle View Hotel, at Lynton. Additional officers to assist the work and to provide staff for these *ad hoc* organizations were loaned by Chief Engineers, Eastern and Western Commands, and by the Commandant, Transportation Training Centre. All gave an excellent account of themselves, and worked capably for the common good.

The command and co-ordination of all engineer effort in these operations was vested from the beginning in the Chief Engineer, South-Western District, Colonel Johnson. All stores and equipment demands and any policy decisions were channelled through him to the Chief Engineer, Southern Command. The latter was responsible for the supply of all stores and bridging equipment from No. 1 C.E.D., Weyhill, and elsewhere. At this latter level also, action was taken to obtain engineer items, including plant, not available from within the resources of Southern Command, together with a variety of other stores and equipment ranging from searchlights to wheelbarrows.

After the bridges were completed, general engineer assistance in the area continued until 5th September. By this time all urgent requirements had been met including the construction of the sea wall to meet the high tides which were expected about this date. Accordingly, operations other than plant operation in Lynmouth ceased on 5th September, three weeks after the first impact of the disaster. Plant continued to work in Lynmouth until the 8th September by which time the tides had come and gone, fortunately without doing any marked damage. Plant was withdrawn, beginning 5th September, but some difficulty was experienced in evacuating it due to the deterioration of the remaining roads out of Lynton and Lynmouth. The last item was finally evacuated from Lynmouth by 10th September.

The conduct of the whole operation was marked throughout by the ability and vigour with which all problems, many calling for skilled improvisation, were met. This applied particularly to the Territorial units concerned, and any misgivings that might have been felt initially as to their capabilities were speedily dispelled by the speed and confidence with which they tackled all tasks entrusted to them.

A tribute must also be paid to all those not prominently in the limelight, but without whose help operations might have been considerably slowed. In particular, the R.A.S.C. drivers—partly "Z" reservists—and those responsible for the actual loading of stores at C.E.Ds. and elsewhere deserve special praise. It was as a result of their efforts that bridging and other equipment arrived at the sites, with what the Military Correspondent of the *Daily Telegraph* described as " amazing promptitude."

Many lessons can be learnt from this episode. Detailed ones will no doubt have become apparent to the formations concerned. The over-all ones were old and tried principles somewhat disguised by the unusual circumstances. Foresight and good communications linked to a simple and therefore flexible plan were the basis of the structure.

Built on to these were imaginative use of the resources available, intelligent improvisation of command and control organizations to suit the peculiarities of the situation, and capable and competent handling of the troops employed. Quick and methodical staff-work resulting from mutual confidence cemented the whole. Enthusiasm, cheerfulness and energy completed a structure which earned praise for its builders from the many who came to inspect it.

A SAPPER AT THE SENIOR OFFICERS SCHOOL

By Lieut.-Colonel J. W. Bossard, M.B.E., R.E.

THE objects of the course, which lasts three months, are contained in the appropriate A.C.I. You may look it up if you are interested. The one I was on was No. 9 Regular Course. There were fifty-eight of us of all sorts, creeds, and denominations, including one from Pakistan, one from Burma, one from Thailand, and one from Egypt. It was planned for sixty, but two had fallen by the wayside.

We were divided into six syndicates. Most of the students came from the Infantry, but there were representatives of many arms—Armour, Gunners, Sappers, Signals, R.E.M.E., R.A.S.C., R.A.O.C. —altogether a very representative gathering. As 50 per cent of them were from the Staff College, and at the end of the course each student is graded according to the course average, one had to be very much *au fait* with " staff duties " early in the course. I had much leeway to make up, particularly as I am a " non-union " man. There were four Sappers on the course—Butler, Calvert, Bloomer, and myself. My syndicate included four infantrymen, one Canadian (R.C.A.S.C.), two Gunners, one R.E.M.E., myself as the Sapper, and one from Tanks.

The school is at Erlestoke Park, a somewhat ugly country house situated in pleasant country in the north-west corner of Salisbury Plain, a few miles from Devizes. A previous course had celebrated its presence with a fire that had burnt down a large part of the house. This caused considerable restrictions to our amenities. Syndicate rooms were situated in the wings of the house and the main part of the building was the mess. Our quarters, that beggared description, were some 300 yards from the house. Half-way between these and the mess stood the lecture theatre, where all central discussions were held. We arrived in snow that lasted a fortnight, and left at the end in pouring rain, and whilst there it did one or the other incessantly. Never have I seen more depressing weather, or ground so permanently water-logged. The moral is simple—if you ever have any choice never go there on a winter course !

Instruction was mainly by discussion ; first within the syndicate, and then centrally in the lecture theatre. To me, this was novel and I took some time to appreciate its value. Much depends on the syndicate leader in stimulating discussion and keeping everyone on their toes, and in that respect we were lucky. In our syndicate it never flagged for a moment. We had a good leader and one of the Gunners was even more argumentative than I, so that, sooner or later, we were at it like dogs at a bone. Plays by the directing staff were admirably produced and whilst teaching many excellent lessons, helped to break the monotony of continual discussion. At first sight the programme led one to believe we were in for a gentleman's existence. Work began at 9 a.m. and ended at 4 p.m. ! But before a discussion on any subject we were given a précis to study in our own time. There were reams and reams of them of excellent composition, and if one was not to be caught at a disadvantage during discourse there was only one answer—burn the midnight oil and read them ! I, who had done no tactics for years, found my time more than full.

The first fortnight was confined mainly to mastering the organizations and establishments of the units and formations we were to use during the course. These included the Infantry Battalion ; the Infantry Division ; the Armoured Division ; and the Armoured Brigade, and dealt with such detail as weapons, ranges, ammunition, vehicle characteristics, communications, and the like, so that, at the end of that time, I knew not only how many Centurions were available and where, but how much first-line ammunition they had ; how much was A.P. and how much H.E. ; the distance they could go before refuelling ; how they communicated with each other, and with the accompanying infantry.

We then each did our first appreciation from the map ; a simple attack as a battalion commander. It was called " Exercise 400." It was most ingenious and thought provoking. There were two courses open ; two lines of approach and two ways to attack ! One appeared as good as the other, but unless you had arrived at your plan in a plain logical way you found yourself changing horses in mid-stream when you got to the " courses open." It certainly taught me the value of a correct appreciation as never before. The Commandant, who sat in on our syndicate discussion and was much amused with our reasoning, told us how it had originated. A General was asked to produce an appreciation for the Staff College entrance examination. He kept putting it off until one morning a letter arrived at his breakfast table stating in no uncertain way that it must be done at once. He threw down his napkin, walked from the dining-room into the garden, looked at the surrounding country and wrote the problem then and there. It certainly was good, and hundreds of officers must have since had much cause for thought.

Then followed the " St. Lo " appreciation, again from the map, and done individually. It was much more complicated than the first. There were several courses open and I shall never know which was correct. If unanimous opinion was a gauge, then the school solution wasn't the right one. We all quarrelled violently with it and arguments waxed for days. The directing staff were highly amused—it was just the instruction we needed.

We went into the country, doing our TEWTS—in the usual order! Two days for a defence scheme at Hag Hill were followed by a withdrawal to a locality several miles north. We spent two days there and came back to the syndicate room to do the advance from the map—Exercise "Ardennes." We went out into the country once more for the attack on Potterne Field, and then the night attack, and spent two days on the Thames at Shillingford on a river crossing exercise. It was so flooded we couldn't tell the river from the rest. To complicate matters we were told that for the benefit of the exercise, conditions were normal. The C.I.G.S. joined us there and gave us a pep talk before we left. The gist of it was there weren't bad officers or bad non-commissioned officers; only bad commanding officers! There were far too many of them and as embryo C.Os. we had better do something about it! We spent the night in comfort in a lovely inn by the river, close to a weir, and on the way back we did the armoured exercise—"Overflow." All this was interspersed with visits to the School of Land/Air Warfare; the Parachute School at Abingdon; the Royal Regiment at Larkhill; the Assault Regiment at Perham Down; and the Infantry School at Warminster. We saw many an excellent demonstration. We did air transport loading exercises; we moved divisions by air; we built airfields in the jungle; and went to the Arctic to hear all about that. We even worked out a complete detailed artillery fire plan for a brigade attack. I now know what a "stonk" is, and something of the Gunner's problems. I would feel happier if I thought he knew something of mine.

We had some excellent lectures. General Gale on training was as lucid as ever. I've never seen a lecturer use his face to more effect, and I found it highly amusing. His language too was a source of glee to all of us. General Horrocks told us of his duties as Black Rod, and of his battles. General Festing took us in detail through the present procedure for selecting officers, and a civilian whose name I forget, gave us a brilliant dissertation on China. He had been a leading Customs official in Shanghai for many years and spoke well and with authority. He was very definitely pro-McArthur. Perhaps the most interesting was Dr. Dunlop of Hamburg who discussed with us the question of German rearmament. Before dinner he described in masterly way the development of the German Empire and its coming to its present pass. After dinner he took the part of a leading German citizen and we his guests. He gave us his reactions as a German to the proposal that Western Germany should re-arm, and asked us individually to suggest ways of doing it. There followed two hours of the most interesting discussion in which I have ever taken part, but, as he summed up, not one of the sixty-odd officers present *could* find a practical answer.

Recreation was a great problem, particularly with winter evenings and the appalling weather. Work ceased on Friday afternoon and the majority went away for the week-end. I took gun and dog, having obtained special permission to take "Cherie," my labrador, in view of the order that no dogs are permitted. Each Saturday I went to the Imber Ranges that are near the school, shooting rabbits of which there are hundreds. They sit out in the long grass and when flushed by the dog present some grand sporting shots. I killed seventy-eight whilst there, and they made a welcome addition to messing, with meat in such short supply. I had never been over the Imber Ranges before and I could not but wonder at the waste in using thousands of acres of such excellent arable land for such a purpose. Half-way through the course we were given a long week-end. I took a warrant and visited Edinburgh for the first time. We came back to the second half to a greatly increased tempo and found life much more arduous. Each syndicate had to produce a TEWT to be tried out on the others. Our subject was the withdrawal. And each had to produce a demonstration—in our case "Harbouring in the Jungle." Some of them were of a very high standard, and script writers had a wonderful time including all the *bon mots* of the course, and taking off the idiosyncrasies of the Commandant, his staff, and several of the students. It was all good clean fun, but very hard work.

We visited the Home Office Civil Defence School at Falfield, in an old house in lovely surroundings, where we saw how well the Home Office and Ministry of Works can do themselves. We were given some excellent demonstrations by some of the civilian staff, and took part in a Civil Defence exercise, based on Bristol where their organization, and staff, are very much on their toes and in the forefront of C.D. training.

Altogether I got great value from it. It was just what I wanted, and what I needed, and I enjoyed every minute of it. It is surprising how "rut bound" and self-centred a Sapper can become unless he himself takes good care to prevent it! The course certainly dug me out of my particular groove. But I was profoundly disturbed by one thing—the surprising lack of appreciation of the Sapper problem by other arms, and especially the infantry. It is always brushed aside with the set answer—"The Sappers will do it"—and somehow or other they always appear to. One is given the impression that we live and work on a totally different plane and can be called down at will, with all we need, right on the dot, to do the job. I found it most disturbing and feel that it is something we must tackle at all levels. Perhaps I'm too impressionable, but consider how much in the field depends on the engineer effort; and that the officers on the course were the battalion commanders of to-day and the brigade commanders of to-morrow. One step in the right direction would be to see that sufficient Sappers attend each course to ensure that there is one per syndicate.

ROYAL ENGINEER OFFICER TRAINING

IN the June, 1952, *R.E. Journal*, we published an article by Captain F. W. E. Fursdon under the above heading.

Since that article was written certain changes in the training of R.E. officers have been approved by the War Office.

The following is a summary of the latest arrangements proposed by the War Office.

1. There have been two main criticisms of the training of regular Royal Engineer Young Officers :—

(*a*) Over-all length of their training period.

(*b*) The system of attachments to field units during the present Stage II period of training.

2. The over-all length of the present training syllabus is in some cases 5¾ years. This means that most regular lieutenants are under training and very few are available for posting to field units.

3. Subalterns undergoing their nominal fifteen to twenty-one months Stage II attachment to R.E. field units are incompletely trained as Sapper officers. Their attachments are liable to interruption by Inter B.Sc. and Cambridge Q.E. courses and the Y.O. is taken away from his unit when he is just beginning to pull his weight.

4. This break in academic studies caused by the long Stage II attachment throws an unnecessary strain on young subalterns working for Cambridge University or the Military College of Science and during their first year of study at these places.

5. Because of these criticisms the programme has been reviewed with the object of providing continuity of academic instruction and of reducing the over-all training period. The revised programme will be put into effect from No. 10 Y.O. Batch on commissioning from the R.M.A. in February, 1953.

6. The new stages of training are as follows :—

(*a*) *Stage I*

This stage will, as at present, consist of 4½ months field engineering training at the S.M.E. and will be given to all Regular Y.Os. joining the Corps from the R.M.A. At the conclusion of this stage, Y.Os. will be entitled to draw Special Qualification Pay (as they are at the moment) provided they satisfy the conditions of A.C.I. 953/51.

(*b*) *Stage II*

This stage will include 12½ months technical training at the S.M.E. and will be given to all Y.Os. joining the Corps from the R.M.A. During this stage, Y.Os. destined for the Military College of Science or Cambridge University will do a three months attachment to field units in B.A.O.R. during the collective training period (July to September) in addition to their technical training. The remaining

Y.Os. will continue their training at the S.M.E. and will not be posted to units until their technical training is ended.

(c) *Stage III*

This stage will include further academic education at either the Military College of Science (two or three years) or at Cambridge University (two years). Only Y.Os. selected for these places will pass through this stage. The technical training of other Y.Os. will terminate at the end of Stage II and they will pass on direct to Stage IV.

Stage III will not necessarily follow Stage II in the case of officers going to the Military College of Science or Cambridge. Some of the subjects covered in Stage II will be taken before they go to Shrivenham or Cambridge, and the remainder when they have completed their studies at these places.

(d) *Stage IV*

This stage will be the same as the present Stage IV, during which an officer will be posted for a normal tour of duty with a unit to gain experience sufficient to enable him to command a Field Troop in peace and to be second-in-command of a Field Squadron in war. Officers will not normally specialize in any of the technical branches of the Corps during this final stage of their training.

ARCHED FLOATING BRIDGE IN TASMANIA

An article under the above heading, written by Dr. H. Gottfeldt, was published in the September, 1952, *R.E. Journal*. Since then information has been received that this bridge was damaged during a severe storm in 1943 (shortly before it was officially opened on 1st January, 1944). The bridge was repaired and strengthened.

Mr. G. A. Maunsell, a consulting engineer, was recently asked however, to advise on the condition and strength of the existing bridge. He considered that the present bridge would survive another storm equal to the 1943 storm, but that it might suffer serious damage from a more violent or prolonged storm, owing to the unknown dynamic effects of wave action.

If it should become necessary to replace the bridge in the future, he recommended a trestle type, built straight across the chord of the arc of the present bridge, incorporating the lifting span in the new bridge.

He recommended the use of hollow cylindrical piles, at the bottom of which a steam hammer could be operated to drive a solid pointed pile further into the bed. The cost of such a type of bridge was estimated at £450,000, but he considered that the existing floating bridge could be re-erected further up the river, where the absence of waves would enable it to function successfully.

BRIGADIER-GENERAL F. D. HAMMOND, C.B.E., D.S.O.

FREDERICK DAWSON HAMMOND, who died on 29th November, 1952, was the son of Colonel Frederick Hammond, C.B., of the 5th Punjab Cavalry, was born on 10th November, 1881. Educated at Temple Grove, Eton and the R.M.A., he was commissioned in the Royal Engineers on 2nd May, 1900.

After completing a course at the S.M.E. he did a short course of mechanical engineering with the Midland Railway and then went to South Africa and remained there after the war with the 47th Fortress Company. He returned to the U.K. in 1906 and was posted to the 29th Fortress Company at Chatham. Two years later he started his long connexion with railway work by building the Baro–Kano Railway in Nigeria.

F. A. Pope of the British Transport Commission writes of him as follows :—

"After leaving Eton, where he was a King's Scholar, he went to Woolwich and then to the South African War (Queen's Medal with five clasps). After the South African War he went on railway construction on the line from Baro to Kano, in Northern Nigeria, under Sir Percy Girouard, who was then Governor. He had worked under Sir Percy in South Africa and was always proud of the fact that Sir Percy had personally offered him the work on the Baro-Kano Railway. This line was built remarkably quickly. At one time the group of Royal Engineer officers in charge held the record for quick track-laying. He then came home and, realizing the importance of transport in any future war, was seconded to one of the British railways. He went to France in 1914 as an Assistant Director of Railway Transport. It was then, as a temporary officer, that I first met him.

"At the end of 1915 he went to the newly formed British Salonika Force as Director of Railways and I followed him there as one of his officers. After setting up the railway construction, transportation and movement organization, he went to the Inter-Allied Communications Commission in France, and in 1919 became head of the Railway Mission to Poland, followed by the post of Director of Communications, Upper Silesia. By then he was known in many circles and, after the war, Sir Henry Thornton put forward General Hammond's name to Lord Milner, who appointed him Special Commissioner for Railways in the East African Dependencies in 1921.

"He inspected and reported on the Gold Coast Railways, the Sierra Leone Railways in 1922, the Nigerian Railways in 1924, also the transport problem of Jamaica. In 1926, he was commissioned by the Government of Southern Rhodesia to report on the finance and administration of the Rhodesian Railways' system. These reports are models of their kind. Unlike so many, the recommendations in them were carried out. I myself had a hand in doing so in Nigeria.

" He inspected and reported on the Iraq Railways in 1926–27, and in 1935 General Hammond accepted the invitation of the Chinese Government to examine and advise on the organization of the Chinese Railway system.

" He was on the boards of the Rhodesia Railways Limited, and of the Mashoneland, Trans-Zambesia and Beira Railway Companies. He was also a Member of the Overseas Mechanical Transport Directing Committee and the Committee of the Ross Institute for Tropical Diseases.

" In 1937, he was appointed to the board of the Central Uruguay Company of Monte Video and in 1939 he was elected Chairman of the Company and of the North Western of Uruguay Railway Co. Ltd., which chairmanship he held until the sale of the railways to the Uruguayan Government in 1949.

" He was an acknowledged expert on railway organization and finance and for years was Adviser to the Colonial Office on such matters. He also reported to the Government of India on the statutory control of railways. So much for his distinguished professional career.

"As a man he was a born leader; he had great strength of character and very high ideals in his private and his public life. He possessed great charm and had perfect manners. He was extremely well read and a great conversationalist. I used to stay with him and no matter what subject arose, he was able to draw on a remarkable memory with aptness and without boredom. He was a real wit and it was a delight to sit at his table. Every officer and every man who served with him or knew him, whether in the army or in civil life, will deeply regret his death."

Brigadier-General Sir Godfrey Rhodes also writes :—

" In the death on 29th November, 1952, of F. D. Hammond, the Corps lost one of its distinguished members, in a rather special sphere.

" I first met F.D.H. in 1908 when it fell to his lot to try and teach a number of us young officers at the S.M.E. something about mechanical engineering, under the general direction of Lieutenant A. E. Davidson (now Major-General A. E. Davidson, C.B., D.S.O.).

" From that date, we went our different ways, not to meet again until 1915, when I found myself commanding a special Railway Construction and Operating Company, destined originally for the

Dardanelles, but diverted to Mudros and finally Salonika, where we came under the command of Colonel F. D. Hammond, as Director of Railways. He later became Assistant Director-General of Transportation. We met again in 1921, when F.D.H. was asked to come out to Kenya, to advise the Government regarding the future organization of the Uganda Railway, as it was then called. As it's Chief Engineer, I had the good fortune to accompany Brig.-General Hammond, over the whole railway system. His subsequent report was of great value to the Governments of Kenya and Uganda, and became the first of many reports made by him on railway matters.

"Curiously enough, though he had never, so far as I know, filled an executive post on any railway, he became well known in the railway world, and an expert on the management and direction of railways. Subsequently he joined many railway boards, notably the Nyassa Railway, Rhodesian Railway and several South American railways.

"F.D.H. was always approachable, always helpful, and always a good friend. He had the useful capacity of being able to sort out and put down on paper the best ideas and suggestions of those he had to deal with. As a result, his reports, unlike some others, contained few mistakes of fact, and were always full of extremely wise and sensible recommendations. They, therefore, still remain standard works of reference in the Library of the Colonial Office. He will be remembered by all who knew him in those early days, right down to the time of his death, as a keen officer, with a penetrating and analytical mind, especially devoted to railway and transportation matters."

Another old friend, Colonel C. F. Birney, adds :—

"I first met Eric, as he was known to his many friends, in the 1914–18 war, when we worked together, at intervals, in the Transportation Branch, again in 1926 in Southern Rhodesia, and at irregular intervals in later years when he was principally occupied with railway affairs in South America.

"Our common interests brought us together ; but out of this developed a regard and friendship which grew with the years. With a quick brain and an alert and critical mind, Eric did not suffer fools gladly, and he sometimes seemed to be impatient and sweeping in his judgements. But he was so obviously sincere and generous minded ; and he never lost his sense of humour. There must be many like myself who can recall some discussions or arguments in which a proper sense of proportion was at once restored by one of Eric's breezy flashes of good humour.

"A valued colleague and old friend has passed away, leaving many happy memories and no regrets."

Brigadier-General FD Hammond CBE DSO

Colonel Sir Charles F Arden-Close KBE CB CMG FRS Sc.D

COLONEL SIR CHARLES F. ARDEN-CLOSE, K.B.E., C.B., C.M.G., F.R.S., Sc.D.

SIR CHARLES FREDERICK ARDEN-CLOSE, who died at Winchester on 19th December, 1952, was the eldest son of Major-General Frederick Close of Shanklin, Isle of Wight; and was born in Jersey, at the home of his grandparents, on 10th August, 1865. He took the name of Arden-Close in 1938, in compliance with the terms of a bequest. He was the eldest of seven brothers, all of whom, except one who died in infancy, served in the Army; five of them, including himself, in the Corps.

After passing through the "Shop," where he was top of his batch and gained the Pollock memorial medal, Close received his commission on 5th July, 1884; and after completing his course at Chatham, was posted to Gibraltar, where he stayed about a year, and was then posted to the balloon detachment. In 1888, he was ordered to India; and went to Calcutta. There, on the advice of his chief, he applied for service on the Survey, and in 1889, was transferred to the Survey of India. He stayed for four years in the Survey of India, and gained a varied experience of practical surveying, mostly in Burma, which he was to put to good use in later years.

In 1893 Close returned to England, having been promoted Captain during the previous year. He was sent first to Chatham, but after two years there, was offered and accepted the charge of the survey of the Nigeria–Kamerun boundary. This task took about a year to complete; and soon after his return to England he was appointed to the staff of the Ordnance Survey. His stay with the Ordnance Survey was, however, short, for, in 1898, he was appointed British Commissioner on the Commission appointed to delimit the boundary between Tanganyika (at that time a German colony) and Nyasaland. This duty brought Close into contact with Sir David Gill, of whom he saw much, and also Mr. Cecil Rhodes, with whom he had an interview before leaving England. In 1899, Close returned to the Ordnance Survey; but a year later, after the outbreak of the war in South Africa, he was ordered to proceed to South Africa in command of a small R.E. survey detachment, charged, rather belatedly, with the task of producing maps for the forces out there, who had been struggling, as best they could, with the problem of carrying on a war ranging over some 800,000 square miles of—to them—completely unknown country, without any maps at all! Before long, however, Close contracted enteric fever and had to be sent back to England; rejoining the Ordnance Survey as soon as he had recovered his health.

In 1902, Close was appointed Chief Instructor in Surveying at the S.M.E., and while holding this post, was asked by the War Office to prepare another edition of a *Text Book of Military Topography* which he had written in 1897. He took the opportunity to recast the book altogether, and produced his well-known *Text Book of Topographical Surveying*, which quickly became, and has remained ever since (after going through three or four editions), the standard work on the subject throughout the British Commonwealth.

In 1905, Close became Chief of the Geographical Section of the General Staff at the War Office. He had been promoted Major in 1901, and became a Lieut.-Colonel in 1908, but this appointment did not then, as it did later, carry the rank of Colonel and he did not become a full Colonel until 1912. The G.S.G.S. was concerned mostly with overseas maps, and when Close became its chief, he took the initiative in recommending the formation of the Colonial Survey Committee, and in trying to get surveys started in the British colonies. He also attended, as a member of the British delegation, the periodical congresses of the International Unions of Geography, and of Geodesy and Geophysics ; and at the meeting of the Union of Geography at Geneva in 1908 he took a leading part in the discussion of the project for the "*Carte Internationale du Monde au Millionième.*" This project had been first proposed in 1895, and had been exhaustively discussed at every congress of the Union held since that date, but without very much progress having been made. Close was quick to perceive that, with map production in all countries being run by governments, not very much was likely to come of discussions between savants representing only scientific bodies or seats of learning. Accordingly, on his return to London, he succeeded in getting the British Government to invite other governments who might be interested in the project, to send duly accredited representatives to a special conference held for the specific purpose of drawing up a working plan. This conference, held in London in 1909, transformed the project from little more than a pious aspiration into a practical working proposition.

In 1911, Close, now with an international reputation, was appointed Director-General of the Ordnance Survey ; but the outbreak of the first World War three years later, interfered with his plans for developing the work, especially the geodetic work, of that department. During his tenure, however, the geodetic levelling of Great Britain was revised, the 1-in. map redesigned, and approval obtained for the appointment of scientific and archaeological advisers to the Director-General. During the war, the civilian work of the department had to be closed down, and its resources were turned over to war work. A detachment, known as O.B.O.S., was sent over to France in 1918, and nearly 40 million maps were printed at Southampton for the use of the armies in France and elsewhere.

Close retired from the service in 1922, on reaching the age limit for his rank in the Army, but continued to devote himself to geographical work and study. Indeed he maintained his geographical interests, and continued his activities, almost up to the end of his long life. His wide knowledge and great experience of all kinds of surveying, his keen mind, his energy and initiative, and, above all, his dignified and yet genial personality, enabled him to fill, with unusual distinction and success, the office of President of a great number of organizations dealing with various aspects of geography. Among offices which he held, he was President of the International Union of Geography from 1934 to 1938, President of Section E (Geography) of the British Association in 1911, President of the Geographical Association in 1927, and in the same year became President also of the Royal Geographical Society, holding that office during the celebrations of the Society's centenary in 1930. He was also, for many years, Chairman of the Palestine Exploration Fund.

Besides his *Text Book of Topographical Surveying*, Close wrote three books, and a great number of technical articles and papers, many of them about map projections, problems of population, and archaeology, three branches of geography in which he was always specially interested.

Sir Charles married in 1913, a daughter of Mr. Thomas Percival, of Shanklin, and had two sons and a daughter. His younger son, then a subaltern in the R.A., distinguished himself in Malaya in the second World War, and was awarded the Military Cross; but he was captured by the Japanese, and died in captivity. His other son, now a Lieut.-Colonel in the K.S.L.I., with his wife and daughter, survive him.

Close was the recipient of many honours and distinctions. He was made a C.M.G. in 1899, for his services on the Tanganyika–Nyasaland boundary commission, a C.B. in 1916, and a K.B.E., for war services, in 1918. In 1919, he was elected a Fellow of the Royal Society, and in 1928 received an Honorary Degree of Sc.D. at Cambridge. He was also an Officier of the Belgian Ordre de Leopold. In 1914 he was invited to give the Halley lecture at Oxford, choosing as his subject "the Geodesy of the British Isles," and in 1927, was awarded the Victoria Gold Medal by the Royal Geographical Society. He was, in addition elected an Honorary member of many foreign geographical societies.

Sir Charles Arden-Close's death marks the end of an epoch in the surveys of Britain; an epoch in which its civil, military, and colonial surveys have been established upon sound and, it may be hoped, lasting foundations; foundations, moreover, in the laying of which he played a leading and distinctive part. He died full of years and honour, leaving behind him a record which few have equalled.

M.N.M.

COLONEL A. G. GADD, M.I.Mech.E., A.M.I.E.E.

ARTHUR GEORGE GADD was educated at Wolverhampton and commissioned from the R.M.A. on the 23rd January, 1919, being one of the first batch of young officers to be commissioned after the 1914–18 war. With the rest of the batch he was posted immediately on commissioning to a Field Company in the Army of Occupation on the Rhine, returning to Chatham in November to carry out the first full post-war young officers course. At the end of this course, Gadd with three others went to the School of Electric Lighting at Gosport for nine months. These four officers were lucky in having as instructors Major H. S. Briggs and Lieut. W. Morecombe, two of the ablest electrical and mechanical Sappers of the time, who put them through a course in the groundwork of electrical and mechanical engineering, rather than confining their attention to the details of searchlights.

After two years in the South Irish Coast Defences and a year at the School of Anti-Aircraft Defence, Gadd was sent on a long E. & M. Course. The War Office was at that time taking a particular interest in well boring and Gadd was the first officer to specialize in this work. In 1927 he was posted to the School of Military Engineering as an Instructor in the Mechanical School and in 1931 went to Gibralter as E. & M. Officer to the Garrison and second-in-command of the Fortress Company. On his return to England he became an assistant inspector in the Inspectorate of R.E. Stores at Woolwich and subsequently at Chislehurst, rising to the position of Deputy Chief Inspector for Stores for the works services. In April, 1941, he was specially selected for promotion to full Colonel and was sent to Washington to organize the supply of engineer stores, being one of the first of his batch to achieve the dignity of red tabs.

It was in Washington that he first contracted the illness which led to his early death. He worked to all hours with a very inadequate staff, and his health suffered.

After two years in the United States he returned to England to the Engineers Stores Depot at Long Marston and thence went to Egypt to the Canal Zone where his health further deteriorated. He was invalided home and after many months in and out of hospital, where he underwent several severe operations, was invalided out of the Corps. From then until his death on 1st March, 1952, he lived at Bournemouth in the intervals of undergoing treatment in Sanatoria for the tuberculosis which caused his untimely death.

Such are the bare bones of his career but there is much more of interest in George Gadd's life story. He was a " real " engineer and as such rendered most valuable services to the Corps. He was a Member of the Institution of Mechanical Engineers and an Associate Member of the Institution of Electrical Engineers and was qualified for full membership. While an Inspector of R.E. Stores early in the last war, he was responsible for much work on the design of the new Inglis bridge which was at that time expected to be the principal heavy bridging equipment. The original design was quite unsuitable for rapid production, requiring tool-room tolerances, particularly for the junction boxes which were castings. Such precision could not be obtained in the daily output of the foundries and an immense amount of modification had to be made before reasonable output could be obtained. Since bridging equipment was urgently needed at the time and the Bailey bridge had not yet been developed, there was considerable heart burning and Gadd never received the credit that was his due for the efforts that he made.

It was while his Department was inspecting sterilizing apparatus that Gadd discovered that it was quite possible, with the standard design, for dressings to go through the process without being properly sterilized and in company with Major A. W. Turner, R.E., developed a simple modification to prevent this. This modification was of great value and the two officers received a War Office grant for their initiative. When they came to patent the device, however, they found that they had been forestalled.

Gadd never allowed any considerations of personal advancement to interfere with his taking the course that he knew to be right. He was a man of great independence of character and a tremendous worker and enthusiast. It is reported that he lectured to young officers at Chatham on his special subject of well boring for 2½ hours, oblivious of the passage of time and the growing restlessness of his audience. He was a most entertaining and shrewd companion at all times. He was fond of riding, sailing and golf, but found his principal happiness in his married life. It may be said that he never received from the Corps the recognition which his ability and industry deserved.

Of the four young officers who went to Gosport in 1921, two have passed away prematurely. Both did most valuable technical work. One went outside the Corps and received appropriate recognition while the other remained in the Corps and did not.

Gadd was married in 1927 and leaves a widow, a son at Aberdeen University and a daughter at school. His fortitude in bearing his long and painful illness, and his refusal to be discouraged by many strokes of fate which came his way will also be an inspiration to his fellows.

K.H.T.

BOOK REVIEWS

GOLDEN ARROW

The Story of the 7th Indian Division

By Brigadier M. R. Roberts, D.S.O.

(Messrs. Gale & Polden, 1952. Price 25s.)

The 7th Indian Division, famous in World War I, was re-formed in October, 1940, to become even more famous in World War II. As with many divisions in the United Kingdom, its training lasted a long time. It was not until the winter of 1943–4 that the Golden Arrow appeared on the battlefield. The Japanese had often fought against units of the Indian Army, which were just as good, but they now met for the first time, units working together as a highly trained division.

That nearly two years had to elapse before the Japanese were confronted with a properly trained formation reveals in a flash how desperate the struggle in S.E. Asia must have been. The wrongly named " Forgotten Army " had, in truth, few of the requisites which are commonly recognized as essential for success in modern war. Lack of equipment made it deficient in fire power and mobility. The exigences of a perilous situation denied it time for adequate training. Yet its obstinate valour made up for these failings and carried it triumphantly through the worst days. By the time the 7th Indian Division delayed in Arakan, the tide of war was running strongly against the Japanese. Even so, the division had to withstand the last desperate enemy offensive in the battle of the " Boxes," around which, to their astonishment, the Japanese swirled in vain. Later on it crossed the Irrawaddy—2,000 yards wide—with equipment which Field-Marshal Slim described as " a few bamboos and a ball of string."

The unmarked small-scale maps are rather a torment, but they do not spoil this admirable account of the closing stages of the war in S.E. Asia. It will be widely studied, not only by our own countrymen, but also by Indians and Pakistanis. B.T.W.

THE STORY OF THE ROYAL TOURNAMENT

By Lieut.-Colonel P. L. Binns.

(Messrs. Gale & Polden, 1952. Price 15s.)

At the time of the Silver Jubilee of King George V, Noel Coward portrayed in *Cavalcade* the power and the glory of Britain at the turn of the Century. In much the same way this pleasing story of the Royal Tournament recaptures the splendour of the military displays, which have been staged from 1880 onwards at Islington, Olympia or Earl's Court. The spirited drawings, reproduced from long-forgotten illustrated newspapers, have a vital sparkle which even the best photographs lack. They are reminders that photography has tended to make good drawing a thing of the past.

The tournament was started to encourage skill at arms and to provide funds for military charities. But skill at arms, even demonstrated by such redoubtable champions as Lieut.-Colonel Betts, had to take second place in the public esteem to pageantry and mock battlefields. The colour and splendour of these pageants enabled the directors of the tournament to reckon their profits in thousands rather than in hundreds of pounds.

Lieut.-Colonel Binns, who tells his story well, is not a mere praiser of the past. His " Cavalcade " goes riding on. Even on the last page another Royal Tournament is about to start—Long may it flourish ! B.T.W.

GENERALS AND ADMIRALS : THE STORY OF AMPHIBIOUS COMMAND

By Captain John Creswell, R.N.

(Published by Messrs. Longmans, Green & Co. Price 18s.)

"From Belisarius to Mountbatten," this book might have been called, or, since it doesn't really get into its stride until 1596, " From Cadiz to Okinawa." It ranges over the seaborne invasions of the centuries, with the author shrewdly analysing the merits and faults of the various systems of command. Finally he pursues this topic inland, and into the present-day realm of N.A.T.O.

You have here, succinctly furnished with examples from the past, all the arguments for unified command under a Supremo and for joint command under General, Admiral and (omitted from title but not from text) top Airman. It is an absorbing subject, and you may feel that without any avowed intention, this book throws light on our Empire and Commonwealth experience of the weaker system somehow proving the lustier. Perhaps at high levels the logical rules don't apply.

The value of this book does not lie only in its main theme of inter-service relations. The accounts of expeditions and campaigns are potted history for which, in unleisurely days, the student will be grateful. Captain Creswell's authorship renders these accounts most excellent fast reading with no loss of drama—indeed, with drama heightened by his dwelliig somewhat on the interplay of personalities. When the personalities happen to be soldier and sailor you are only very occasionally reminded of his warning in the preface that he cannot hope to write completely without bias !

The final short chapter is a noteworthy summing up on the command question, arming the reader for debate or examination. One feels this book should achieve a lasting place in military literature—and in due course be reprinted with just a few more maps. T.I.Ll.

JAN CHRISTIAN SMUTS

By J. C. Smuts

(Published by Cassell & Co., London. Price 25s.)

Britain's one-time enemy, upon whose death a British Premier said " A light has gone out from the world of free men," has been faithfully served by his biographer son. Though " partly writing in a spirit of eulogy " this second J. C. Smuts pays South Africa's wise statesman-soldier-philosopher a just, and hardly a slavish tribute, providing for his readers a renewed contact with the far-seeing mind of the General himself.

This title " General "—he was really " too old now to change names " as he said when made a Field-Marshal—may conceal the fact that this highly successful soldier was not, as such, a professional. After taking degrees in both arts and science at Stellenbosch, he studied law at Cambridge. Strict regard for justice, the courage of his convictions and the breadth of his interests characterized him always, so it was without contradiction, that this " ruthless " executioner of the spy Colyn in 1902 and Haig's supporter over the costly Passchendaele front, could remark " Worship—and pass on " when he saw a rare flower on the veldt.

Modestly written, this book follows the life-course of this " son of the veldt " in a straightforward manner, only in the last section, and for a few moments, allowing the crowded picture of world events to overshadow the stern and always distinguished idealist, whose understanding of psychology enabled him to handle Welsh miners on strike, Kaffirs, Boers, British and world statesmen alike with the same peaceful efficiency.

The present unhappy state of his country underlines his absence from it. The background to this state is a valuable aspect of the book, whatever the political views of the reader may be.

Though this great raconteur of war stories failed to write his memoirs, his son records many memorable episodes on which Smuts loved to reminisce. The General's unwitting failure to capture his would-be captor in 1901 is one of these, as is the story from the East African campaign in the first World War, when the Royal Engineers accomplished what their own Chief thought to be the impossible, and built a bridge over a raging torrent in very difficult country in time to cut off retreating Germans with their native troops.

While at Cambridge, Smuts had written a study of Walt Whitman, never published, but holding the germ of his later *Holism and Evolution* which constitutes his personal contribution to fundamental thought about the principle governing all life, namely that the whole is greater than the sum of its parts. This concept underlies his feelings about South African Union, the Commonwealth as a whole, the old League of Nations and his part in the later San Francisco Conference, for all of which he worked so hard.

This book, as the great man's life, contains a message of faith in the future, in the eventual triumph of good, however dark and stony the paths that must be trodden to make any progress towards it. "It is in the nature of the soul, as of all life, to rise" he said, when dedicating the memorial to the dead of the 1914–18 war on his well-loved Table Mountain, and though he lived to see so much of his life's work brought to nought—for the moment—this far-sighted and doughty warrior never finally despaired. L.R.W.

THE NILE

By H. E. Hurst, C.M.G., M.A., D.Sc.

(Constable & Co. Ltd. Price 30s.)

Within the limitations of 320 pages, Dr. Hurst modestly claims only to have told an accurate and up-to-date story of the River Nile of interest to the general reader, free from a mass of technical detail. This he has achieved amazingly well, and produced an excellent and easily readable book.

The first ten chapters deal briefly with local history from ancient to modern times and the early ideas on irrigation—we know that Aeschylus writes of Egypt as nurtured by the snows and that the Lunae Montes appear in Ptolemy's map, both referring to the snow-capped Ruwenzori Range of which one side drains into the Nile—and then describe the 4,160 miles of river from its mouths in the Mediterranean to its source near Lake Tanganyika. This is vividly written, and gives one a complete picture of the very varying terrain, peoples and occupations, flora and fauna on both sides of the river and its tributaries: it also reveals the profound intimate knowledge acquired on site by the author during many and long fact-finding visits to all these areas.

There follow two important chapters on the more technical subjects of climate and hydrology, kindly couched in language for the layman, which betray the continual exploration, research and classification being carried out.

The last two chapters tell of the major projects of water-control already in existence and discuss the theory of short and long term water-storage, and outline future projects to ensure the conservancy and control of almost every precious pint! Work on the Owen Falls dam at the outlet of Lake Victoria is in hand: the immensity of this new reservoir can be gauged when one reads that it is as large as Scotland, and to raise the level of the lake by 4 ft. would need the entire outflow of the Thames for forty years.

The increasing population, with its corollary of more food and irrigation, is a cogent factor in the Nile projects, as indeed are the policies and politics of the several countries through which the river flows—all much in the public eye at the moment.

Inside the end covers of the book are two maps covering the whole course of the Nile, and there is a generous supply of photographs and sketches: the graphs and diagrams are clear and most informative. The index is good.

The book is so fluently and delightfully written that it must have been a labour of love to Dr. Hurst, and a fitting finale to his forty-five years of work for the Egyptian Government. He says he went to Egypt in 1906, recruited by Captain H. G. Lyons, late R.E., Director-General of the Survey of Egypt. Your reviewer feels a remote affinity, for he himself joined the Sudan P.W.D. in that year, and twenty-seven years later succeeded Colonel Sir Henry Lyons, F.R.S., as he then was, as Director of the Science Museum in London. E.E.B.M.

REINFORCED CONCRETE

By Oscar Faber, C.B.E., D.C.L. (Hon.), D.Sc., etc.

(Published by E. & F. N. Spon Ltd., London. Price 30s.)

In this book the author has distilled the experience of many years and, as he has a happy knack of choosing simple and graphic examples to illustrate his points, has produced a refreshing and clear exposition of what really matters in reinforced concrete design. The book cannot be used as a general text book, too much is left out and it all sounds too easy, but it should be read by advanced students and all those whose mind is caught up in the mass of calculations and logic that has in the past been built upon the slenderest assumptions in the study of reinforced concrete.

The book falls into three parts:—

(*a*) Four chapters which study the general properties of concrete and reinforcements. In addition to the usual effects of water/cement ratio, grading and shape of aggregate, curing conditions, a study is also made into the effect of shrinkage and creep on the long-term stresses in the members of a R.C. structure. The author shows that the working stresses adopted in design according to Code of Practice 114 are safe, but can vary very widely from the stresses actually occurring in even simple structures, the general effect of creep and shrinkage being to reduce the working stresses in the concrete and increase those in the reinforcement.

(*b*) Five chapters on the elementary principles and practice of simple reinforced concrete design. This section covers principles only in general, but ends with a chapter on columns which contains some excellent practical tables for column design.

(*c*) Seven descriptive chapters on piling, silos, shell concrete, water retaining structures, chimneys, factory-made concrete and pre-stressed concrete. The chapter on shell concrete is particularly clear and well illustrated and holds out hope that this subject may be covered by design procedures that are within the scope of the ordinary engineer. There are tables of stresses to be allowed in factory-made concrete design which are of great value.

The book is well provided with good clear diagrams and has a reasonably comprehensive index. H.C.G.C-T.

TECHNICAL NOTES

THE MILITARY ENGINEER

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

July–August, 1952

"New Army Engineer Equipment," by Colonel O. B. Beasley.

The author was Commanding Officer of the Engineer Research and Development Laboratories at Fort Delvoir, Virginia, from August, 1949, to May of last year, and gives an interesting review of progress made, and being made, to date, under the various sub-heads of Military Equipment, M. and E. Equipment, Topographical Equipment, etc. Korean operations have proved a valuable testing ground for recent modifications to engineer equipment. The author also pays tribute to the co-operation of the Royal Canadian Engineers who join their efforts with the Corps of Engineers in several important fields. Through the Royal Canadian Engineers the industrial and scientific resources of Canada can be made available for the solution of joint problems.

"Human Relations in Engineering," by Rear-Admiral Joseph F. Jelley

The author, the Chief of Bureau of Yards and Docks, emphasizes that engineering is not all plans and projects. Too frequently the young engineer fails to realize that he can only accomplish his objective through the medium of human beings. Men cannot be treated as machines and it is only with a genuine understanding of his fellow men and an attitude of sympathetic helpfulness than an engineer can achieve outstanding success in his profession. An eminent engineer, asked to comment in the light of his experience on the adequacy of the early training he had received, replied that while the engineering courses were excellent, there was one great deficiency he had spent the rest of his life trying to correct. Not only did his university fail to teach him anything about the art of dealing with people, but none of his teachers had ever mentioned the importance of such a thing to success in his profession.

September–October, 1952

"Reaction of Buildings to Atomic Blast," by Sherwood B. Smith

The author, lately Chief of the Protective Construction Branch of the Chief of Engineers, and since 1950 employed in the Armed Forces Special Weapons Project, considers that discussion of the problems of building in the atomic age is a first and vital step in reaching decisions as to what can be done to increase our chance of survival in case of attack.

He presents in broad terms the effects of the atomic bombing on buildings in Japan and follows this with an analysis of the probable behaviour of buildings exposed to similar blast effects. He claims that while it is true that nearly everything within close range of an atomic explosion will be destroyed, this area is small in comparison with the very large areas in which varying degrees of damage result. It is in these fringe areas that the greatest improvement to resistance to blast and fire can normally be accomplished with the maximum result for expenditure of effort.

Interesting photographs and diagrams illustrate the article.

ECONOMIC DEVELOPMENT IN CANADA

(*The Engineering Journal of Canada.*)

The development of the economic resources of Canada is of particular importance and interest at the present time. The following papers, recently published in *The Engineering Journal of Canada*, give useful information about the potentialities of the Dominion and the problems of development :—

September 1952
Nechako–Kemano–Kitimat (Aluminium plant).
Trans-Mountain Oil Pipeline.
Integrated Forest Products Operation.
October 1952
Structural Timber.
Planning and Construction of the Columbia Cellulose Mill.
Iron Ore Development in Quebec and Labrador.
The Defence Construction Programme.
November 1952
Canada—Engineering Opportunities Unlimited.

The general reader may find it helpful to read the last-named article first.

HYDRO-ELECTRIC POWER DEVELOPMENT

(*The Engineering Journal of Canada*, dated September and November, 1952.)

To serve what will be the world's largest aluminium reduction-plant, the Aluminum Company of Canada are constructing a hydro-electric power installation which will be in some respects the biggest on the earth's surface, requiring its own harbour and a new town to accommodate some 50,000 people. Economic factors and design are discussed.

Until 1950 the allocation of water from the Niagara River was based upon definite quantities for the U.S.A. and for Canada. In 1950 a new Treaty was signed, and each country is now allotted half the excess flow over a specified quantity. In consequence, the Ontario Hydro-Electric Power Commission have started the Niagara No. 2 Development Project, which will have a rated capacity of 1,200,000 h.p. in twelve equal units, in addition to a capacity of 560,000 h.p. from the No. 1 Development, the first unit of which went into operation in January, 1922.

The new project involves two tunnels, of finished diameter 45 ft., each some 29,000 feet long ; a canal, about 200 feet wide and 12,000 feet long ; a forebay, headworks and power-house.

Design features and statistics are not covered in detail in this article, but the general planning and organization are clearly described. A most interesting feature is the use of models to check theoretical design, and to determine incalculable factors such as turbulence and flow where waterways cross or the cross-sections change.

TRANS-MOUNTAIN OIL PIPE-LINE

(*The Engineering Journal of Canada*, dated September, 1952.)

This paper contains a clear historical record of the growth in Canadian oil discovery, production and refining, and shows how the cost of transportation over the great distances across Canada is being minimized by the use of oil pipe-lines. In 1950, the only crude-oil pipe-line in existence was a portion of the Portland–Montreal line. By the end of 1954 there will be a major pipe-line and tanker system extending from Montreal to Vancouver.

The production from Alberta is expected to reach 390,000 barrels per day in 1955, of which 100,000 will be absorbed by the Prairie Provinces. Of the balance, some 92,000 barrels per day will be moved eastwards by pipe-line to the Great Lakes area, leaving 198,000 barrels for transportation, through the Trans-Mountain Oil Pipe-line now under construction, to the Vancouver refineries, where products will be available for the British Columbia market and for ocean shipment.

The methods used in locating and designing the new 700-mile pipe-line from Edmonton to Vancouver are described, and construction procedure is briefly outlined.

CONSTRUCTION

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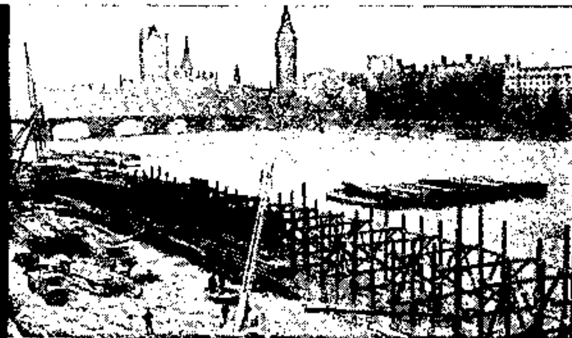
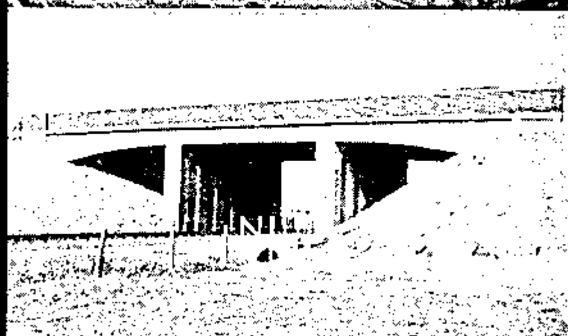
SOUTH BANK
RIVER WALL



GOSPORT
ROAD
BRIDGE



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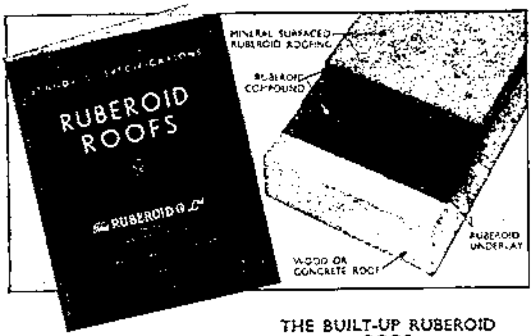
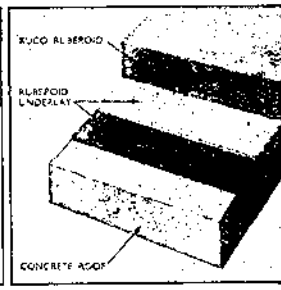
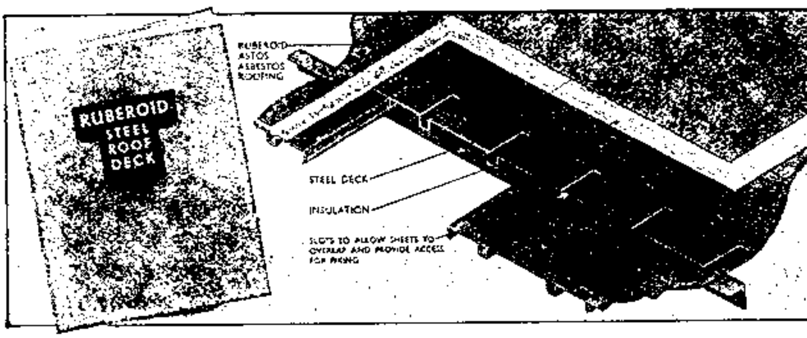


THE BUILT-UP RUBEROID ROOF



THE RUCO-RUBEROID ROOF



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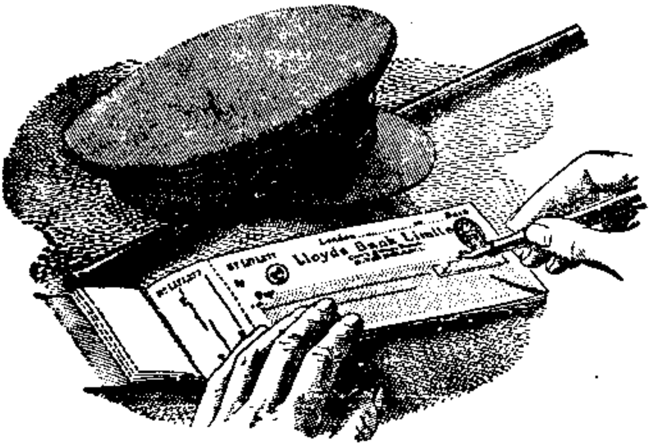
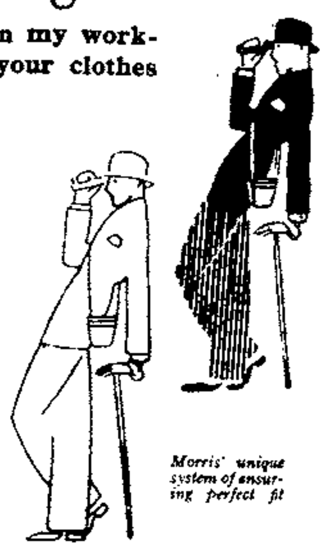
177 COMMONWEALTH HOUSE, 1-19 NEW OXFORD STREET, LONDON, W.C.1

R. 40





Morris' unique system of ensuring perfect fit