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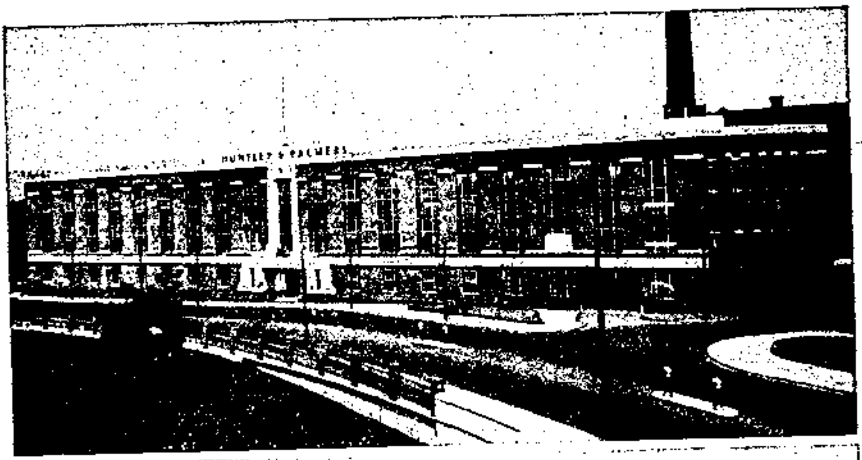

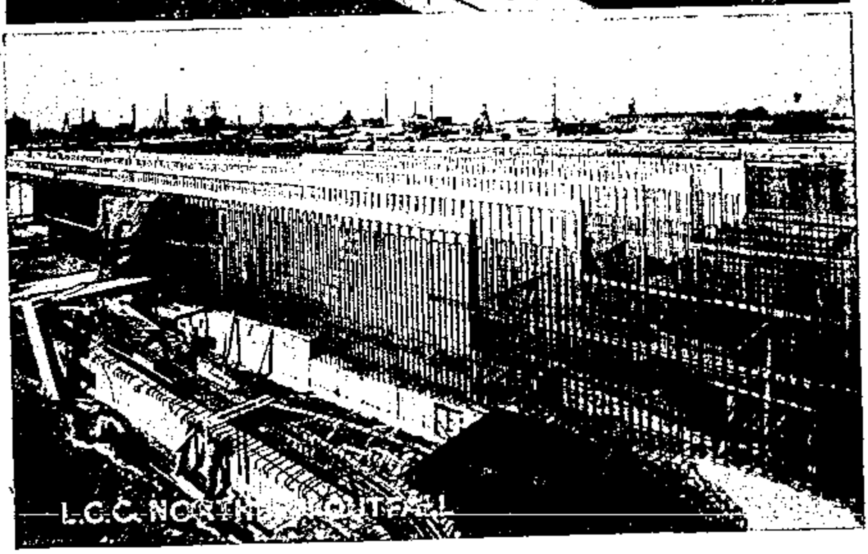

# THE ROYAL ENGINEERS JOURNAL

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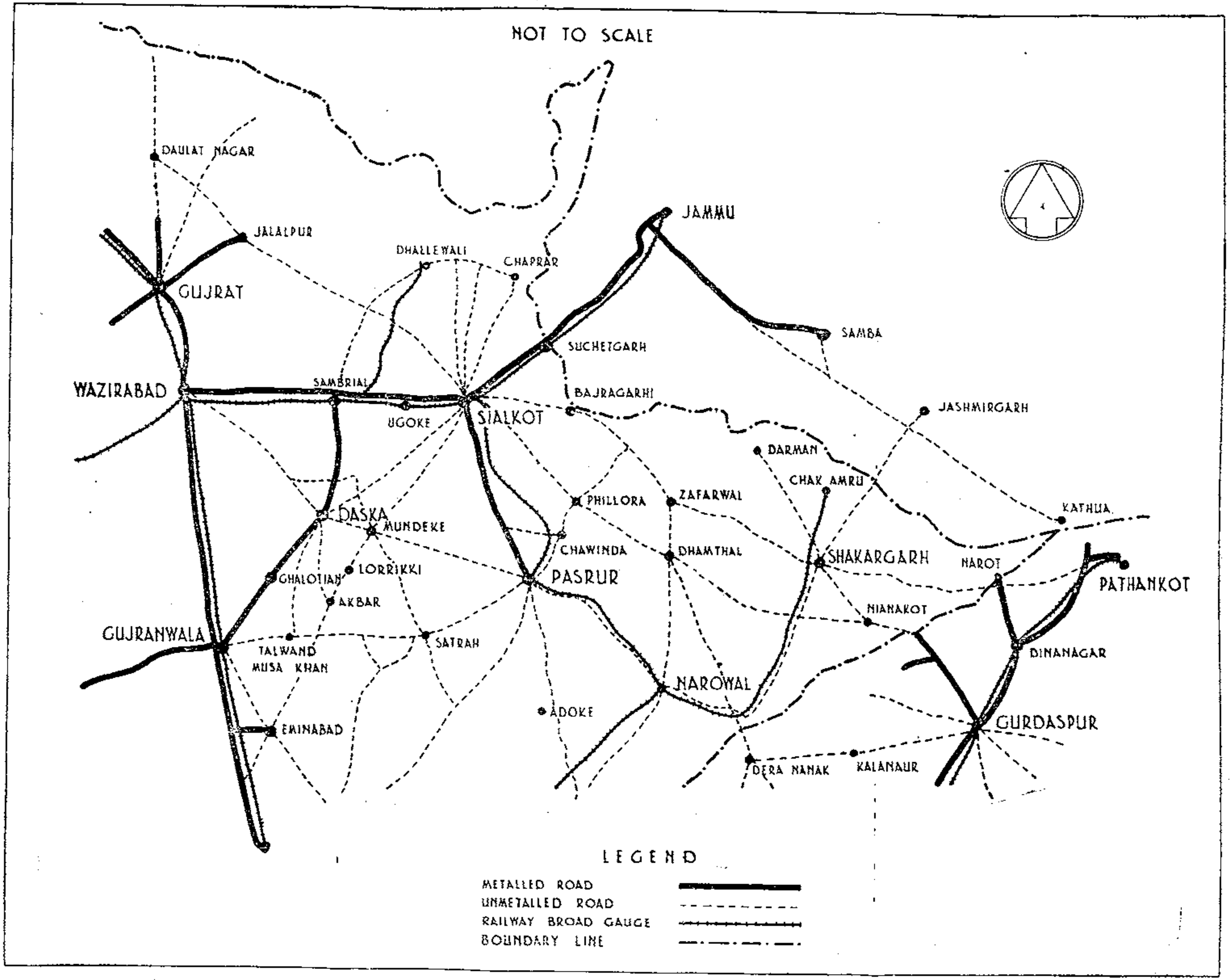
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DERA NANAK
KALANAUR
LEGEND
METALLED ROAD
UNMETALLED ROAD
RAILWAY BROAD GAUGE
BOUNDARY LINE

# SAPPERS AT SIALKOT

*By* "ANONYMOUS"

THIS is the story of the activities of four companies of the R.I.E. and R.P.E. in Sialkot Sub-Area, West Punjab, during the disturbances of 1947. Many similar events occurred in other parts of the Punjab, but at Sialkot it was essentially a Sapper affair. For this reason the story is written around the activities of these units.

Sialkot Sub-Area comprises the civil districts of Sialkot and Gujranwala. For about 130 miles it lies on the borders of the new Dominion of India and the Indian State of Jammu and Kashmir.

Trouble started in February, 1947, when two companies of the Frontier Force Regimental Centre (Lieut.-Col. A. J. W. Macleod, D.S.O.) were deployed along the N.W.R. between the Alexandra Bridge, on the Chenab River, and Muridke, both in Gujranwala district. Throughout the hot weather the situation remained tense at Wazirabad and Gujranwala, which were held by 9 (later 29) British Fd. Regt. At this time 622 Gp. R.I.E. (Lieut.-Col. D. W. R. Walker, M.B.E., R.E.) was forming at Sialkot, and eventually consisted of 42 Fd. Park Coy. (Major A. D. M. Dunne, R.E.), 14 Fd. Coy. (Major C. A. Walker, R.E.) and 15 Fd. Coy. (Major Kumar, R.I.E.). Owing to the absence of the Gunners and lack of active infantry, 42 Fd. Park Coy. was required to take over the guarding of vital points, and 14 and 15 Fd. Coys. to find a mobile column. During the hot weather all three of these companies carried out intensive patrolling to restore confidence in the countryside.

At the beginning of August, the Punjab Boundary Force was formed under the command of Major-General T. W. Rees, C.B., C.I.E., D.S.O., M.C. Gujranwala civil district was removed from the operational command of Sialkot Sub-Area, and Sialkot itself placed under the operational control of 14 Para. Brigade, (Brigadier Scott, D.S.O.). The Boundary Force was retained in the Indian Army, as opposed to the Dominion Armies, and an appeal was made by the Commander for the highest standard of discipline to be maintained. 14 and 15 Coys. were Madrassis and Dominion of India troops, and 42 Fd. Pk. Coy. were P.Ms. and Pakistanis.

In Sialkot Civil District are four Tehsils ; Sialkot, Pasrur, Daska, and Narowal, and on 17th August, 1947, Shakargarh was added. The sketch map attached shows the district, which is extremely poorly served by roads. There is a good metalled road from Sialkot to Sambrial and Daska, and another from Sialkot to Pasrur. Beyond this there were only dry weather tracks and canal roads, unusable in the monsoon. On the Jammu boundary there are no roads. The railway was also of great importance. From Sialkot broad-gauge lines ran to Jammu, Sambrial and Wazirabad ; and to Amritsar, via Narowal. From Narowal branch lines ran to Lahore, via Raya and Shakargarh. There is an aerodrome at Pasrur, and "Auster" strips at Sialkot and Gujranwala.

At the beginning of August trouble broke out in Lahore and Amritsar, and Muslim refugees started to arrive in Sialkot via Narowal. From that time onward the situation in Sialkot, which had previously been relatively quiet, began to deteriorate. On 12th August, alarming reports were received of raids across the Ravi River into Narowal Tehsil, and on 13th August, the Brigadier with the Deputy Commissioner and Supt. of Police visited Narowal by borrowed jeep. In spite of the Brigadier's warnings, the D.C. insisted on staying to write a lengthy report and, overcome by darkness, his jeep was bogged in the Degh nala. Eventually bullocks were obtained from a neighbouring village, but it was 2200 hrs. before Sialkot was reached. They were met by alarming news and the sight of a blazing city. Trouble had broken out in the afternoon. Colonel J. Hubert, D.S.O., 16 Punjab R.C., had taken command and had two companies in the city. His determined action undoubtedly did much to save the situation. The only troops available were made-up companies from F.F.R.C. and 16 P.R.C. The next day reinforcements arrived, consisting of the Sikh Coy. of 4 F.F.R. and Dogra and P.M. Coys. of 3 Baluch. A good deal of shooting of murderers and looters was necessary, but after the first few days the curfew was strictly obeyed and eventually order restored, though it was never possible to stop arson. The Army had to take complete control as the Police were entirely communal in their outlook. On the restoration of order the Coy. of 4 F.F.R. and P.M. Coy. of 3 Baluch were withdrawn and 33 Para. Fd. Coy. R.P.E. sent from Amritsar, where this unit had had a very severe experience losing two B.Os. killed.

On 14th August, 15 Fd. Coy. left for Narowal, where they were faced with utter chaos. The Hindu mohallas of the city were burned by Muslims, and Sikhs from across the border were raiding Muslim villages. The police were quite unreliable and civil control had broken down. 14 Fd. Coy. were therefore sent to reinforce Narowal, and Major Walker, R.E., placed in command of the force. Meanwhile the monsoon gathered force and all roads became impassable ; there remained the railway to Sialkot, on which there was no regular service. Finally only the threat that 42 Fd. Pk. Coy. would take over the railway persuaded the civilian personnel to carry on. Sapper Officers were busy working signals, deserted by their personnel, and persuading engine drivers.

The trouble spread quickly to the rural areas, and attacks on trains started. Information from the Police dried up, and two trains were actually attacked within 800 yards of Cantonment. Rumours poured in and the two scratch companies which could be mustered were continuously being dispatched on wild goose chases. The trouble always took place in the opposite direction. The Cantonment itself was threatened by mobs of peasants and the perimeter defence scheme put into action.

On 17th August, the Boundary Commission made their very belated decision, and the fat was in the fire with a vengeance. The civil district of Gurdaspur (less Shakargarh), in which the Pakistan Flag had been hoisted with rejoicings on 15th August, was handed over to the Dominion of India and the flag came down. Sialkot immediately became a frontier district and a steady stream of Muslim refugees started to cross the Ravi into Pakistan. At the same time the monsoon started to strengthen. This award was not expected, nor had there been any planning for mass evacuation.

The situation as regards transport and communications was very low. A Sub-Area H.Q. is an administrative unit, not equipped for an operational rôle. Apart from the unit transport of the Engineers there were some twelve 3-ton lorries, "made" from a neighbouring Brigade. For Signals dependence was on the Field Company, and a few Signallers and sets from 16 P.R.C. All dry weather tracks were by now unusable.

For some time the balance between the Muslim and Sikh peasants was very even. Within reach of the metalled roads the Army was able to maintain some order, but beyond them there can be no faithful record of the extent of the slaughter. To add to the difficulties parties of troops started to come across the border from India to evacuate their families. This caused a spate of rumours, and on two occasions these parties were wiped out by the local police. Civil control was non-existent, but martial law was not declared, a ticklish situation.

On the 14th August, Hindu and Sikh refugees had started to pour into the Cantonment from Sialkot City. Three refugee camps were started under the control of 16 P.R.C. (1) and F.F.R.C. (2) and (3). The Staff was entirely military with camp M.I. Rooms. Rations were extracted, rather like an obstinate tooth, from the civil. The number of refugees rose to about 15,000. At the same time No. 4 Camp was opened at Narowal by Major Walker, R.E., and held about 10,000. A Company of a field ambulance and a field hygiene section were also placed under his command. When Muslim refugees began to arrive at Sialkot, No. 2 Camp was converted to a Muslim Camp and after fifteen days taken over entirely by the civil. This was the only refugee camp ever run by the civil.

As a considerable number of refugees wished to go to the Hindu State of Jammu, arrangements were made to evacuate some 10,000 by rail and road. Trains were invariably attacked, but these attacks were beaten off by the mixed guards of F.F.R.C. Road convoys to Suchetgarh fared less happily. Tonga drivers demanded Rs. 100 for the six mile journey, and several tonga loads were murdered and looted, three men being stabbed in Cantonment.

Before long, it became apparent that the Sikh peasants were, although holding their own, very anxious for military protection of their villages. The Brigadier was unable to guarantee this, and a mass evacuation started. The first sign was a column of 40,000 from Narowal and Shakargarh tehsils, with animals, who burnt their villages and marched under their Sardars to the Ravi Bridge. By superhuman efforts Major Walker and his Sappers kept this column separate from the incoming column of Muslim refugees so that there was no clash or casualty. At this time the road from Sialkot to Narowal was unusable ; in fact the whole countryside was a sheet of water, with three Sapper lorries lying in the Degh nala. The Brigadier's only method of transport was the train, which ran at any hour. The return journey often took sixteen hours. All efforts to obtain a trolley or diesel car were fruitless.

The tap was now open and refugees poured in from all directions. Major Janjua with one Coy. of 3 Baluch was dispatched to Daska and Major James, R.E., with 33 Para. Fd. Coy. to Pasrur to cope with the situation. Major D. M. Dunne, R.E., with 42 Fd. Pk. Coy. was given the task of establishing the camp. It should be explained that 622 Gp. R.I.E. had by this time broken up, and all Sapper units were directly under Sub-Area. Operational control of 14 Para. Bde. was at this juncture withdrawn.

Within two days 70,000 refugees had assembled at Daska, 30,000 at Pasrur and 10,000 at Ujjoke, where 15 Punjab R.C., who had just arrived from Ambala after an adventurous journey, took over.

Major James acted with incredible energy. In a short time he had established Nos. 5, 6 and 7 camps, and by hook or by crook found and issued food. So hard did this company work that of the three B.Os., two fell sick of exhaustion and the O.C. was a mass of prickly heat. As refugees continued to pour in, evacuation by foot via the Degh nala to Narowal was ordered. Escorts to Narowal were provided by 33 Para. Coy., thence to the Ravi by 14 and 15 Fd. Coys. In spite of numerous attacks on the convoys, the only serious casualties were incurred in an attack on a passenger train in which an over enterprising N.C.O. had packed 300 refugees with a guard of three men.

At Daska, in No. 8 Camp, the situation was not so satisfactory. The refugees were in the open and the stench and conditions were appalling. On medical advice the Brigadier decided to get the refugees on the move, hoping by change of ground to avoid cholera and disease. A move to Sambrial (No. 9 Camp) along the canal banks with a halting camp was ordered. To feed these refugees every military lorry was utilized and foraging parties dispatched to abandoned villages.

Meanwhile at Narowal the situation was more or less out of control. About 100,000 Muslim refugees had crossed from India. The country was flooded, and the one platoon of 14 Fd. Coy. at Jassar was powerless. There was no suitable place for a camp, and cholera broke out. The railway line was strewn with corpses, and burial became a major problem. No doctors nor cholera vaccine could be obtained. The scene was pitiful in the extreme, the stench unbearable. By now it was apparent that evacuation by rail was the only solution. Capt. Nabi Alam, the S.S.O., succeeded in "making" a rake lying at Wazirabad and this train steadily shuttled from Wazirabad to the Ravi Bridge for a month. A new Deputy Commissioner had by now arrived, and allowed the use of half the daily passenger train for refugees. Boundary Force was abolished and Sialkot Sub-Area came under Pakistan Command (Lahore Area).

Evacuation by rail was now the obvious course, and all plans were adjusted to this end. A start was made at Sambrial and Ujjuke, and before long a technique was evolved. The packing of a refugee train is a fine art. First the women, sick, and aged go into the compartments. The luggage is then hauled on to the roof. After that it is a "free for all." When neither the tender, nor the roof, nor the buffers were visible, the train moved off. Five thousand is the record, 800 to each bogie. The escort travelled on the engine and in two parties at the middle and end of the train. These refugee trains returned with Muslims from Jassar and Naruwal. The evacuation of Daska was accelerated by moving foot columns, each 5,000 strong, along the direct fair-weather track to Pasrur, staging for the night at Kotli Faqir Chand. Those who were unable to march waited at Daska until M.T. could be made available to move them to Sambrial, where a special train was sent to collect them. The evacuation rail-head was now moved to Pasrur, the evacuation of Sialkot camps being left to the end. By this time 33 Fd. Coy. and the Dogra Coy. of 3 Baluch were quite worn out, and Major Blackburn, 16 Punjab, took over at Daska and Major Mohd. Ghulam, F.F.R.C., with 512 Garrison Coy. at Pasrur. Two trains a day were run from Pasrur to the River Ravi; 33 Fd. Coy. took over the train guards from F.F.R.C. There were several attacks on these trains, but all were beaten off. One foot convoy guarded by 512 Garrison Coy. was seriously attacked at Alipur Saidan and suffered about 200 casualties. This was the first attack on a convoy which had achieved a real success.

Some five miles from Pasrur lies the village of Klaswala. The Sikh Sirdars and pensioned officers and V.C.Os. gathered some 40,000 villagers into this area, forming No. 11 Camp. This Camp was entirely run by the headmen. It was kept scrupulously clean, and the evacuees were divided into six sub-camps. Major James, R.E., visited the Camp regularly, and a Platoon, first of 33 Fd. Coy., and later of 3 Baluch was provided as guard. There were several cases of cholera, which were immediately segregated. An I.A.M.C. Captain was detailed to live in the village. These Sikhs resolutely refused to move until orders were received from the Sikh leaders in Amritsar. These eventually came about 16th September, and an operation for evacuation planned. On 21st, 22nd, and 23rd September, refugee trains were run from Pasrur, and on the 23rd September, in glorious sunshine, a Column of some 23,000 Sikhs with horses, cattle, and carts started on the trek to India. The escort consisted of one Coy. of 3 Baluch, and 14 Fd. Coy. R.I.E. In spite of the state of the track all their carts were winched through, and on 24th September, the Column had laagered at Narowal. Attacks had been sporadic and there were no casualties. In fact it is a regrettable fact that the number of cattle increased en route by one hundred.

At Narowal they were but eight miles from India, but then the clerk of the weather again took a hand. Torrential rains poured down, the nalahs rose in spate, the railway was washed away, and with it the road. The escort with difficulty escaped with their lives, and many animals and carts were washed away. However the herculean efforts of 14 Fd. Coy. and the 3 Baluch, eventually succeeded in getting all the refugees, and the majority of animals and kit into India. Major Walker had by now, acute dysentery, and both the Field Companies were withdrawn to Sialkot after six weeks ceaseless toil under the most discouraging conditions imaginable. They had twice refused the Brigadier's offer of a relief.

There was little rest for the Sappers, for roads and bridges had to be re-repaired. 14 and 15 Coys. left for Kasur in Lahore Sub-Area and 42 Fd. Park. Coy. took on the repair of the dry weather track from Pasrur to the Ravi river. 33 Fd. Coy. were still employed as Infantry, and Platoons were dispatched to guard the India and Kashmir frontiers at Shakargarh, Nainakot, Chaprar and Bajragahri. Their highly efficient V.C.Os. and excellent communications were a god-send, and they were now the only active unit with transport and communications left to the Brigadier. On 4th November, 1947, all Sapper units passed back to the command of the C.R.E. which really ends the tale.

It is unfortunate that the writer has not the gift of vivid description, and the narrative is more than dull and fails to give its true value to the achievement of Sapper units in Sialkot. Except for one company of Infantry they were the only active units in the hands of the Commander. They alone had transport, and communications, which were the vital factors. What was even more important was their immaculate discipline. It is true that they were all class units, and so remained internally undisturbed in the general transfer between the two Dominions. However the men themselves in the P.M. units were very worried, as many of them had not heard of the fate of their families left in East Punjab. The Madrassis were not affected in this way. Their impartiality, fairness and smartness did more than anything to maintain the discipline and morale of the army in Sialkot, which as a result retained its prestige. At all times they were a credit to their famous Corps, and it is felt that their record should be known to Officers of the Royal Engineers in other parts of the Empire.

# THE ASSAM LINES OF COMMUNICATION

*By* BRIGADIER R. GARDINER, C.B.E.

1. The development of a number of Lines of Communication was one of the main responsibilities of India Command between 1940 and 1945. The initial development of the railway and river L. of C. in Iraq was followed by that of the Lease-Lend route through Persia. When these responsibilities were transferred from India Command they were replaced by other similar problems even more complex. These included a serious examination of the possibility of a route to China through Tibet, including the use of Yaks ; a L. of C., also to serve China, which, however, left India by way of her most westerly frontier, namely that with Persia, via the resuscitated railway terminating at Zahidan ; and finally what was known as the Assam L. of C. The route via Tibet, fortunately perhaps, was never attempted, while that through eastern Persia was mainly for the benefit of the U.K.C.C. and was of so limited a capacity that the return obtained from the effort put into it is open to doubt. The Assam L. of C., however, was required for three reasons, firstly as the maintenance route for the 14th Army on the Burma frontier and in Burma itself, secondly to serve the American airfields from which was operated the " Hump Route " to China, and thirdly to serve the American base from which was projected the Ledo Road into Burma and China, later known as the " Stillwell " road. This article describes some of the problems connected with this L. of C. and how they were overcome.

2. Until December, 1941, when the Japanese entered the War, India's rôle had been that of supplying Middle East and Iraq with troops and supplies and stores of all sorts. These included much Transportation equipment consisting of track, bridging, metre gauge locomotives and rolling stock and river craft. There had as yet been no direct threat from the East where, in any case, as far as India was concerned, there were China, French Indo-China, Siam, Malaya and Burma lying between her and Japan.

In Burma potential danger from the East had already made itself felt, due to the difficulties of her neighbour China in the so-called China " incident " which had been going on with Japan since 1935, and which had resulted in the building during 1938–40 of the Burma Road. In spite of this comparative proximity to an existing war between one Axis partner and a potential ally, even in Burma only minor preparations for a possible spread of the war in the East were made—limited resources precluding anything more.

On 7th December, 1941, the Japanese bombed Pearl Harbour and in a flash the war had encircled the world. The sinking a few days later of H.M. Ships *Repulse* and *Prince of Wales* did much to make all in India and Burma realize that real war was now close to their frontiers. Rangoon was first bombed on 23rd December, 1941, practically the only air defence being provided by a very gallant party of American civilian airmen, who until shortly before had been engaged in operating an aircraft assembly plant for American aircraft for China.

Disaster followed and within five months the allied forces had been forced out of Burma, a defence line was formed along the Indian frontier, and the Assam L. of C. came into being.

3. The Assam L. of C. was, in fact, a complex system of ports, railways, rivers, roads and pipe lines. This system requires some general description in order to appreciate the problems arising from its development.

The main starting point of the L. of C. (see plate I) was the Port of Calcutta, but this was by no means the only one. There were in fact innumerable fingers, the tips being different depots throughout India. Calcutta Port can however be considered as the thumb and a great deal of the traffic from India passed through the Calcutta area since this was the only broad gauge route. Considerable development was made to the facilities of Calcutta Port but this article will not deal with them. The rail system of N.E. India was also served by the small port of Chittagong, but this port, except for P.O.L., was used almost entirely for maintenance of Arakan and the East Bengal airfields, and did not otherwise serve the Assam L. of C.

From Calcutta an I.W.T. route and railway run parallel to each other to the north-east extremity of India.

Forming an inverted " L " is the valley of the great Brahmaputra river— " Great " is entirely the right adjective for this waterway which forms a navigable artery from the sea near Calcutta to Dibrugarh, 1,100 miles away, and is unbridged throughout its length. In the monsoon period this river is in places twenty-five miles wide, whereas in the dry weather difficulty is found in keeping channels open. Except for one spot it runs through alluvial plains and its course varies from year to year and often from month to month.

4. Parallel to this river is a railway system. Far from being the simple route so often depicted in diagrams of imaginary L. of C., this railway has several feed-in points and alternative routes in addition to that of the Brahmaputra, and also a road system. The railway system started from Calcutta with a broad gauge line to Parbatipur, where it was joined by a metre gauge line from Mokameh, Benares and Lucknow. From Parbatipur a single, metre gauge line ran eastwards to Amingaon, on the right bank of the Brahmaputra. Here was situated a wagon ferry, at the only place on the Brahmaputra, after leaving the Himalayas, at which there are really permanent banks. From the left bank terminus at Pandu the metre gauge, still single line, continued to its terminus at Ledo.

Between Parbatipur and Amingaon the line runs parallel to the Himalayas and at right angles to the natural drainage and as a result was very susceptible to breaching. From Pandu onwards the line runs through some of the worst malarial country in the world and with several heavily graded lengths.

5. Forming a chord to this main or northern route is another metre gauge line skirting the south of the Khasia Hills and besides providing the sole rail approach to Chittagong also joins the northern route at Lumding. Immediately south of Lumding this line runs over a heavily graded section involving the use of special locos and is very susceptible to damage during the monsoon. It should be noted particularly that both rail routes involve trans-shipment from broad gauge (5ft. 6in.) to metre gauge and a wagon ferry crossing. The northern route also had numerous cross links with the I.W.T. route. This meagre rail system may be compared with that serving the North West Frontier of India. The N.W. Frontier, the traditional danger spot and the route by which invasions have taken place or have been threatened during centuries, has, since the advent of railways been provided with a network of broad gauge lines, many of which are classified as strategic and are in no way a commercial proposition.

6. Lastly, mention must be made of the road system. In 1941 there was no road connecting Assam with the outer world nor any into Burma. A road did run from Pandu to Dibrugarh with a link to Manipur Road and thence to Imphal. At that time therefore the use of this road was limited to taking traffic to and from the I.W.T. route, a point which was a most valuable feature of this complex L. of C.

7. Until the withdrawal from Burma commenced in 1942, this L. of C., rail, river and road, was designed to serve a quiet valley whose main trade arose from tea gardens and the oil production of Digboi. Many block sections were fifteen miles long and traffic was light. Within a few days the railway was suddenly called upon to deal with, first, hundreds of thousands of refugees, many in the last stages of exhaustion, then reinforcements of both troops and stores from India, and finally exhausted troops from Burma. The traffic was, as invariably occurs in these cases, greatly in excess of capacity and the organization necessary to compete with the conditions was non-existent. Clearance facilities for the supplies and stores being brought up the L. of C. were insufficient and blocking back resulted on a line with no suitable regulating stations. The result was congestion of the worst type ; station after station holding trains unable to proceed and engines forced to drop fires.

8. It took weeks to clear the chaos and before the control later organized on the line had become effective a major disaster occurred. This was the breaching of the line west of Amingaon. Two major bridges were completely destroyed and in spite of every effort this line could not be restored until five months later. It is interesting to note at this point that in making the repairs, expense was, in this case, no object and since then there have been no further breaches of this line.

9. This breaching gave us practice, rather earlier than we would have liked, in the use of the flexibility, referred to previously, of the L. of C. due to linking of the rail and I.W.T. routes. As can be seen from the map, it was possible, for example, to use the I.W.T. route from Dhubri and Pandu to assist in overcoming the dislocation caused by the breaches.

10. During the summer and winter of 1942, first steps were taken to develop the B. & A. Rly. in order to increase the capacity of the metre gauge line. It was too early to make any very definite plans of the long term requirements of this L. of C., but in April, 1942, a proposal was put up to double the metre gauge northern line throughout. This was turned down and the works were at first limited to providing additional crossing stations to reduce block sections to a maximum of four to five miles, increasing both the length and number of loops at some stations and adding additional siding accommodation at Lumding to act as a regulating station. Near Manipur Road work was commenced, in the monsoon of 1942, on an advanced base and railhead combined to serve the projected route into Burma via Imphal and Tamu. The only site possible was one in dense tropical forest and the utmost difficulty was experienced in carrying out the survey. Quite literally tunnels had to be cut through the jungle along which to sight theodolites and if, as frequently happened, obstructions were found on one of the alignments selected a new tunnel had to be driven.

11. Besides initiating the first development works, orders were placed in May, 1942, for 100 metre-gauge 2–8–0 locomotives and 3,000 wagons. These were actually ordered as a preliminary forecast of our future requirements in Burma, it being assumed that they would take two years to supply. In fact, the first of these locomotives arrived in India from the U.S.A. in December, 1944. India had sent large numbers of metre gauge locomotives and wagons to Iraq in 1941/2 and an acute shortage of this equipment was now felt.

12. As regards development of the I.W.T. route, the first step was to stop all further dispatches of river steamers to Iraq. But twenty-six of the most modern craft had already gone and although twenty-two were later returned this was a slow work and was not effective till the winter of 1944/5. These craft, designed only for inland waters could only undertake the long

voyage from Basra to Calcutta in the non-monsoon months and each required a complete overhaul on arrival back in Calcutta.

13. In the N.E. corner of Assam in 1942, the first steps were taken in a project which was taken over subsequently by the Americans and became the " Stillwell Road." The original reason for this project was to provide an alternative road L. of C. into Burma and China from India, since, with Mandalay held by the Japs, the Imphal route was obviously not available when considering a link with China, which country was now completely cut off from the outside world. The first survey party for the project was formed from Transportation personnel, and besides the road alignment, work also commenced on the necessary railhead facilities. In fact this was the beginning of a huge base area which later also served the numerous American airfields, construction of which commenced in the winter of 1942/43, and from which was operated the supply route to China.

14. By April, 1943, it was becoming clear what the final load on the Assam L. of C. might total—and a joint Mov. and Tn. paper was prepared for the Q.M.G. setting out the developments required to provide a total capacity of 10,000 tons/day. This figure included lift by both I.W.T. and rail but the immense length of the I.W.T. route precluded it carrying more than a very small proportion of the total—its average maximum lift never exceeded 1,500 tons/day. In December, 1941, the physical capacity of the L. of C. was approximately 2,000 tons/day by rail and 1,000 tons/day by I.W.T., although operating standards and lack of station and terminal facilities brought the tonnage handled by rail to 600/1,000 tons per day. This paper caused much discussion as naturally the bill for the development was a big one and included the doubling of the metre gauge line throughout its length and the construction of a single line bridge over the Brahmaputra. As usual the Financial Pundits shook their heads and eventually on 13th August, 1943, the Q.M.G. presented it to the Chiefs of Staff, India. They were convinced of the necessity, but still not so the Financial Department. Then on 15th August, came a telegram from the Combined Chiefs of Staff then meeting at Quebec under Mr. Churchill and President Roosevelt. It gave instructions that the Assam L. of C. was to be developed forthwith to a maximum actual capacity of 7,500 tons/day. Our original figure of 10,000 tons/day had allowed for a twenty-five per cent safety factor to cover breaches, earthquakes and other acts of God and man! We really felt that Tn. was at last on the map and there followed an orgy of telegrams to the War Office placing orders for stores not available in India, including further locos and rolling stock. The target date for the completion of the development was set as 1st January, 1946.

15. During the first half of 1943, the American Air Supply route to China from Assam had been developing and a new load was imposed on the railway L. of C. This was the construction materials needed for the airfields. It was a difficult load because it was a local one and subject to rapid fluctuations. Although local, it was so heavy as to interfere with through long distance traffic. It also absorbed a large number of much-needed wagons. Even after airfields were completed the subsequent construction requirements never seemed to diminish. Larger planes arrived, necessitating in some cases almost complete reconstruction.

16. By the middle of 1943, the "build-up" on the Assam front had commenced and traffic demands continued greatly in excess of capacity. Priorities had to be carefully assessed, one of the most difficult being to allot one to the movement of construction materials required for the railway development project itself. The weight of these materials amounted to approximately 1,125,000 tons, including bricks, sand, gravel, ballast and permanent way materials.

17. This is perhaps a suitable point to describe briefly the general Tn. and Civil organization as applicable to this L. of C.

As has been mentioned, the railway concerned with the L. of C. was the Bengal and Assam Rly. with H. Q. in Calcutta. This railway, like all others in British India, was a Government owned one and as regards general policy came under the Railway Board, a technical body which formed the Railway Department of the Government of India and whose office was at New Delhi.

In 1942, the District system was in vogue on the Bengal and Assam Rly., with its headquarters at Calcutta, under which general control of all departments was centralized in Calcutta. It very soon became clear that the B. & A. Rly. personnel alone would be unable to handle the additional load, both as regards traffic and engineering works, so as Transportation Units of the R.I.E. were raised, they were drafted to the L. of C. to assist. On the open line these units worked directly under the civilian District Officers, but in the case of certain engineering projects, such as the advanced base at Manipur Road, the work was done as a military project under the charge of a Railway Construction Engineer who was also C.O. of a H.Q. Indian Rly. Construction and Maintenance Group, responsible to D. Tn. India. This worked fairly satisfactorily, but on the operating side the system inevitably left the H.Q. Rly. Op. Gp. no technical work other than to watch the technical efficiency of their units. In 1943, the railway adopted a Divisional organization under which control was to a large extent decentralized to Divisional Superintendents, one of whom was situated at Gauhati. At about the same time the engineering work on the railway was reorganized and a Construction department created with a Chief Engineer Construction in charge. Ordinary open-line engineering works and maintenance remained separate, but, perhaps unfortunately, not under the Divisional Superintendent who, therefore, was in fact only responsible for operating. In 1944, a further development took place on the operating side with the arrival of the American Military Rly. Service, which is dealt with later.

The Port of Calcutta was run by the Port Commissioners, who, in turn, for general policy, came under the War Transport Department of the Government of India.

The Inland Water Transport was run by two large commercial concerns, the Rivers Steam Navigation Co., and the Indian General Navigation and Railways Co. Their offices were in Calcutta and their local interests were looked after by a number of Agents at up river stations.

On the Tn. side there was an A.D. Tn. Assam, who, after first being under D.D. Tn. Calcutta, was later separated from that office and came directly under D. Tn. G.H.Q. As regards Movements, D.D.Mov., Calcutta, was responsible for the whole of the L. of C. with A.D's. Mov., at up country stations—D.D.Mov. came directly under D.Mov. at G.H.Q. India.

18. During 1943, the American interest in the L. of C. increased greatly, and in September, 1943, the American Q.M.G. and Chief of Transportation, after a visit to Assam, came to Delhi and expressed the opinion that greater capacity was obtainable from the railway system. They offered to send, therefore, an American Railway Grand Division consisting of five Rly. Op. Bns., Transportation Corps, to operate the northern metre gauge section of the Rly. L. of C. They guaranteed to operate the programme as laid down by the Quebec Conference, whereas the Rly. Board expressed some doubt as to their ability to do so. On 1st February, 1944, therefore, the Military Railway Service of the U.S. Army took over responsibility for operation on the line from Parbatipur to Lekhapani.

**Photo 1.**—Locomotive working wagon ferry at Pandu.

**Photo 2.**—Lumding-Manipur doubling. Typical length through jungle.

# The Assam Lines Of Communication

Photo 3.—Temporary piled bridge for new double line at Gauhati.

Photo 4.—Lumding-Manipur doubling. New bridge at Diphu.

# The Assam Lines Of Communication 3-4

19. One of the first results of this drastic step was a revision of the development programme. The American methods of immediately increasing the traffic were relatively simple. They consisted of (*a*) increasing the length of trains from fifty-five 4-wheelers to 110 and 125 (*b*) increasing permissible speeds, (*c*) cutting preferential trains to a minimum, (*d*) reducing the key locking at certain stations to a minimum, (*e*) better all-round supervision. These measures were undoubtedly effective and were made possible entirely by the large amount of white supervision now available. Even so, accidents were many, chiefly due to coupling failures on long trains. The metre gauge stock was not provided with vacuum brakes and many of the older wagons were not really fit to run under the conditions imposed by the M.R.S. However, bull-dozers are provided on the establishment of every American Rly. Op. Bn. and these quickly cleared the line and, quite rightly, these accidents were considered to be the normal cost of getting the abnormal traffic through.

20. This increase of operational capacity permitted a reduction in the length of the line to be doubled, and instead of 632 miles only 228 miles were in the end so treated. Nearly every passing loop had, however, to be lengthened to accommodate the longer trains and on certain definite bottle-necks the doubling was duly completed. The most important of these bottle-necks was that between Lumding and Manipur Road, a distance of forty-three miles through difficult country.

21. The biggest modification in the programme was the dropping of the Brahmaputra Bridge project. Instead, coupled with really efficient railway operation at the ferry ghats, we doubled the floating equipment and raised the capacity from 250 wagons per day each way to well over 1,000.

22. The Quebec programme required the maximum capacity of 7,500 tons a day to be reached by 31st December, 1945. In fact the capacity by January, 1945, was 9,000 tons a day. Once access to Rangoon was secured, the traffic on this L. of C. rapidly dwindled. The operation of this L. of C., from the time the American M.R.S. took over in 1944, was a good example of inter-allied co-operation. Officially the M.R.S. worked under the direction of the General Manager of the Railway but in fact they were more or less one hundred per cent independent. They even went so far as to issue their own free passes! Both B. & A. Rly. civilians and R.I.E. personnel worked directly under the American Rly. Op. Bn. Commanders. Some doubt had been expressed as to whether this would succeed, but the G.I. seemed to have a way with the Indian very similar to that of our British O.Rs. and there was never, at any time, any friction. The B. & A. personnel in fact improved in efficiency beyond all expectation and it was most refreshing to see a pointsman *running* to man his points instead of his normal way of strolling down the platform chatting with all and sundry and probably having a cup of "char" on the way.

23. On the engineering side control and execution remained with the British. The B. & A. Rly. were responsible, with a lesser or greater degree of help from Tn., except for defined works which were taken over by Tn. and carried out independently. (See Plate II.)

The more important of these works were :—

(*a*) The railhead advance base at Manipur Road, already mentioned.

(*b*) A new river ghat at Neamati.

(*c*) The doubling of the forty-three mile Lumding—Manipur Road section.

(*d*) Re-laying of fifty miles of the Hill Section south of Lumding.

(*e*) The "Stillwell" Road railhead at Lekhapani.

These works were all carried out by organized Labour units on a semi- military basis under the direction and direct control of Tn. Units. Indian Pioneer Corps units were also sometimes available. An early attempt to rely on ordinary civil contractors proved a complete failure, particularly while work was being done during the monsoon. The civil pioneer units, which were raised under Indian States auspices, were a great success and after a few weeks' experience produced quantities of work far in excess of any contractor.

Throughout there was an acute shortage of mechanical equipment for earthwork. In 1944, a small Tn. M.E. Section was scratched together with plant mostly borrowed from the Americans, but except for this all work was done by hand labour.

The A.D. Tn. stationed at Gauhati, after the advent of the M.R.S., in fact, acted as Chief Engineer to the Commanding General of the M.R.S., as well as, of course, being D. Tn's. representative, and thereby exercising control over all Tn. units.

24. So much for the railway portion of the L. of C. As regards the river, I have already explained that development was restricted owing to lack of craft. Steps, were, however, taken to improve some of the ghats and to build an entirely new one at Neamati to serve both Manipur Road and the American airfield area. An important feature of this ghat was that it was sited below a shoal area of the river below Dibrugarh and allowed fully loaded barges to go through to river-head instead, as previously, having to reduce loads to pass the shoals.

These I.W.T. improvements were largely a matter of providing adequate railway facilities to meet all foreseen eventualities, including the provision of alternative ghats. The nature of the river and its banks precludes anything in the way of a permanent or even semi-permanent river port with quays or suchlike.

The question of provision of adequate and experienced labour at the ghats to load and off-load was also dealt with and in 1943, Indian Docks Sections were raised specially to control this labour.

Until 1944, the Government of India had little control over the operation of the steamer companies and, inevitably, military requirements were difficult to explain, even when the Japs were on the Indian frontier. In 1944, however, Government control was applied, equivalent almost to requisitioning.

25. Finally, mention must be made of the road system. In 1942 there was absolutely no road connexion between Assam and the rest of India or with Burma. There was the so-called Assam trunk road running from Goalpara through Gauhati and Jorhat to the Dibrugarh and Digboi area, with a very inferior link at Jorhat with the road from Manipur Road to Imphal. There was also the road to Shillong. The whole of this system was low capacity road with bridges limited to three-tonners. Its value in 1942 was therefore negligible and its maintenance under army traffic became a huge problem.

However, the need for relief capacity, however small, was great and a programme of raising the standard of existing roads was embarked upon. Maintenance was to a great extent undertaken by the Army. In addition, the problem of moving the thousands of vehicles up and down this L. of C., and particularly over the wagon ferries, led to the construction of the Assam Access Road from a rail-head at Siliguri on the broad gauge railway and the construction of an M.T. off-loading point at Bongaigaon, whence as many vehicles as possible proceeded on their own wheels to their destination, so relieving the congestion at Amingaon ferry. This project required an M.T. ferry between Jogighopa and Goalpara, which was organized and worked initially by Tn. I.W.T. and incidentally provided a valuable training instrument.

26. Whilst all this development took place on the L. of C. itself, a corresponding development of depots and bases occurred in India proper. A Reserve Base for all items was built in 1942, at Benares, convenient to serve the L. of C. either by metre gauge direct or by broad and metre gauge via Calcutta or Mokameh. In 1943 work commenced on a Reserve Base at Panagarh, on the main line of the East Indian Rly. 80 miles from Calcutta, designed to serve both the Assam L. of C. and subsequently the Port of Calcutta, when direct shipments to Rangoon could be restored. Numerous depots were also created in the Calcutta area including many for American stores.

27. It should be particularly noted that although most of the L. of C. was situated in A.L.F.S.E.A. territory, it remained throughout a G.H.Q. (India) responsibility as regards Mov. and Tn. Local administration rested with the A.L.F.S.E.A. formations and an added complication was the M.R.S. who were under H.Q., U.S. Army Forces, China, Burma and India at Delhi.

28. A major deficiency on the L. of C. in 1941 was its telecommunications. On the railway there was no railway control system in existence. One was installed during 1943, but such was the shortage of materials that even the wires were second-hand and the circuits were more often broken than working.

The arrival of the M.R.S. brought with it, much improved telecommunications including teleprinters. The installation of this equipment was of the greatest help as it permitted greatly improved control of the long L. of C. and better information of the ultimate destination of wagons. Previously almost constant congestion existed on the railway above Manipur Road with traffic for the airfields and Ledo Base, particularly as, until a regulating station could be constructed at Charali in 1944, there was only limited accommodation in a constricted yard at Tinsukia.

29. Mention must also be made of a project which although not a Tn. one was an integral part of the L. of C. I refer to the pipe lines, British and American. The British project aimed at relieving the rail route over the hill section from Chittagong of bulk petrol traffic, and the first stage of the scheme was a pipe line from Badarpur to Manipur Road which was later extended both ways, to a sea terminal at Chittagong and to a pipe head at Kalewa in Burma. The American project was part of the Quebec programme already mentioned. It consisted of two pipe lines from Calcutta to Ledo, and later one of these was extended along the " Stillwell " Road into China, a really great achievement.

Both these vast projects, with the relief they afforded the L. of C., were of the utmost value in easing the movement and operating problems.

30. The Assam L. of C. took roughly three years to develop. Until the winter of 1943/44, capacity was always insufficient to meet all demands, but from then on nearly all demands were met.

Such an L. of C. requires team work of the highest order and in this case it existed and success thereby was assured. By 1944 the morale of everyone on the L. of C. was at its peak and even the humblest coolie was inspired by some of this enthusiasm. One particular R.C.E. issued a weekly news-sheet telling his men how their part of the development project was progressing. His H.Q. was at a station called Diphu, which merely consisted of a passing loop and one short siding, midway between Lumding and Manipur Road. His slogan was " *Forward to Diphu.*" Final linking of the track having reached Diphu he issued his last bulletin in which he explained that the slogan had become so well known that when any wagon was found without a label the R.T.O. or Yard Master had got into the habit of ordering it " Forward to

Diphu" to the subsequent embarrassment of the Station Master at that diminutive station. Having congratulated all ranks on their great achievement he wound up with "*Forward to Tokyo*—(That's bitched the R.T.Os. and Yard Masters!)".

31. The major lessons from the experience of this L. of C. are not new. They are summarized below :—

(i) Control of *all* movement on a complex L. of C., such as the Assam one, is the first essential. It must be complete and centralized.

(ii) Once more the lesson was taught, in 1942, that adequate clearance facilities at a railhead are essential.

(iii) Civil practice requires maximum safety in operation, and in a country such as India the operating rules cater particularly for this. If the maximum is to be obtained from available railway resources some relaxation of these normal practices must be permitted and the highest dividend will result from an increase of experienced white supervision.

(iv) Tn. must be given a firm target to plan for in ample time. In monsoon countries, although we proved in Assam and later in Burma that the monsoon need *not* mean a complete cessation of work, it does definitely limit both quantity and quality. Such work as major bridges cannot be done during the monsoon.

(v) In planning allocation of capacities Tn. requirements for Tn. development works must be given suitable priority. Tn. Stores are bulky, heavy and usually awkward to handle. Tn. minimum requirements on the Assam L. of C. worked out at one train per day at a time when the total capacity for stores trains was eight to ten trains each way per day.

(vi) If operations are taking place in Eastern or similar countries, and ample supplies of Mechanical Equipment are not available, a properly organized labour force is essential. Civil contractors could not do the job under the conditions experienced in Assam, particularly during the monsoon.

(vii) The importance of adequate telecommunications was fully brought out, and the lower the capacity of the railway the greater this need will be. Had better communications existed in 1942 much of the congestion on the B. & A. Rly. would have been avoided.

# SKETCH MAP OF ASSAM L.of C. AND LINKS WITH BURMA. (1945).

PLATE I.

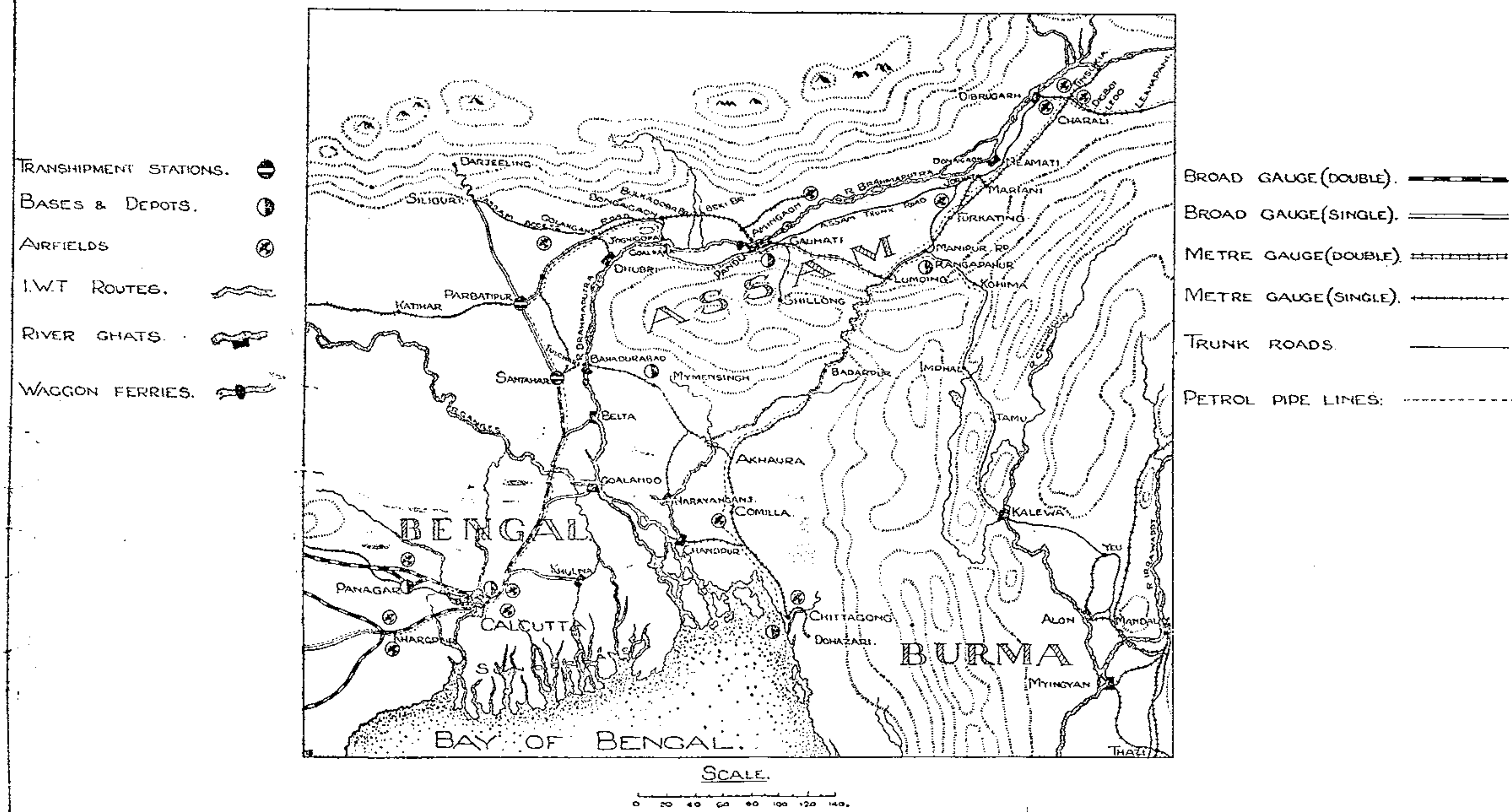
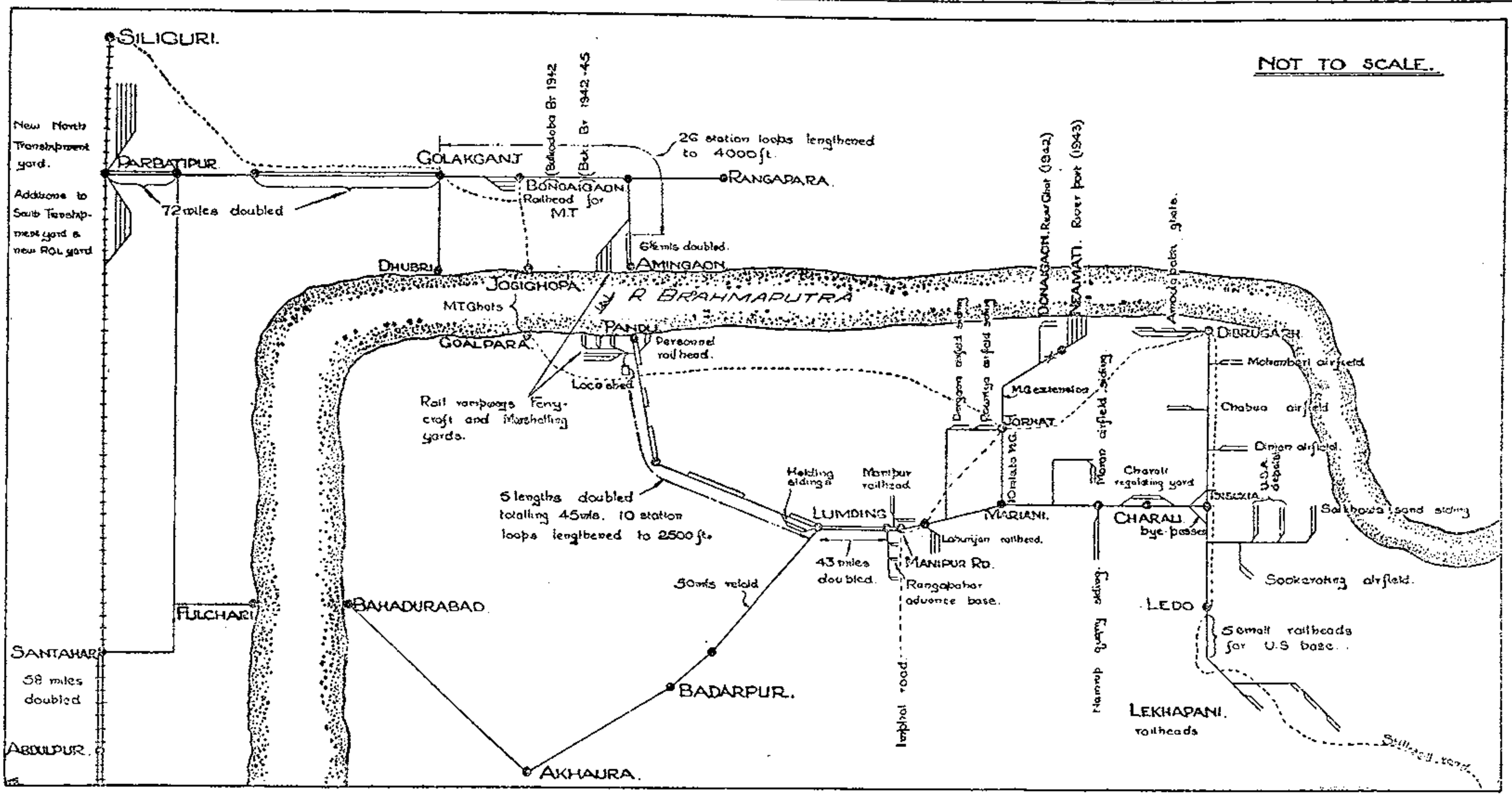


PLATE II.

# DIAGRAM OF ASSAM L. of C SHOWING CONSTRUCTION PROJECTS 1942-45.




Broad gauge railway (Single) — Metre gauge railway (Single)

Roads

Broad gauge railway (Double) — Metre gauge railway (Double)

# CIVIL AFFAIRS PLANNING FOR THE FAR EASTERN TERRITORIES, WITH PARTICULAR REFERENCE TO MALAYA

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PLANNING for Civil Affairs in the Far Eastern territories during the 1939–45 War was the responsibility of the United Kingdom Government in connexion with Burma, Siam, Malaya, the Borneo territories (i.e. Sarawak, Labuan, Brunei and British North Borneo), French Indo-China and Hong Kong.

ESTABLISHMENT ADMINISTRATION

A fundamental issue was the form of government which should be set up in the British territories in the Far East when they were first liberated.

Towards the end of 1942, His Majesty's Government decided that not only in Burma, but in the other British territories in the Far East, it would be essential, in the first place, to establish military administrations under the control of the Senior Officer in command of the troops which liberated the territories. This conclusion was reached upon the following considerations which, it will be observed, are directly or indirectly founded on military expediency :—

(*a*) Law and order must be re-established quickly ;
(*b*) The safety of the liberating forces must be ensured ;
(*c*) Lines of communication must be restored as quickly as possible ;
(*d*) Urgent relief supplies must be imported and distributed to the civil population ;
(*e*) The human and material sources of the country must be quickly reorganized and directed to the further prosecution of the war.

It should be noted that the projected military régime for these liberated British territories would not derive its authority from the Rules of International Law. It was to be a domestic and executive act of the Sovereign Power—based on purely practical considerations. The organization to be set up was described as a " military administration " and not as a " military government "—the latter term being reserved for the form of government set up by an army invading a hostile country on the principles set out in the Hague Convention of 1907. These military administrations in the British territories were to be established by proclamation issued over the signature of the Military Commander.

RESPONSIBILITY FOR THE MILITARY ADMINISTRATIONS

For the purpose of discharging their responsibilities for the effective carrying on of the military administrations, the Military Commanders in each territory concerned were to be provided with a Chief Civil Affairs Officer (C.C.A.O.) with appropriate Civil Affairs Staffs as integral parts of the military organization of their commands. Planning for the military administrations of the respective territories was the responsibility of the C.C.A.Os.

It was considered that the Military Administrations should, as far as possible, avoid dealing with major political issues which should be left for the Civil Governments to handle when they resumed control, but it was realized that the Military Administrations would inevitably be called upon to handle a number of social, economic and political problems which had no military aspect but which could not await the restoration of Civil Government. In regard to these the War Office and the Military Staffs maintained, very close contact with the Burma and Colonial Offices, both during the period of planning and after the liberation of the territories. Indeed, the principle was established that the Chief Civil Affairs Officers should have a dual responsibility. In the first place, in regard to all matters of direct or indirect military concern, they were answerable to the General Officers Commanding-in-Chief and through them to the Supreme Allied Commander and the War Office. Secondly, they were responsible for the administration of their territories to the Burma Office or the Colonial Office in respect of all other matters which had no military implications.

### Duration of Military Administration

The planners were directed to assume that the military administrations would last for a period of six months from the date of the complete liberation of the territory concerned. In practice, this proved to be a reliable forecast.

### Planning Procedure

Planning commenced long before any definite military plan had been settled for the liberation of most of the territories concerned ; in the case of Malaya, planning began in July, 1943, though the first troops did not land in the country until September, 1945. The planners were, however, directed to devote their time to drawing up a complete picture of the military administration in all its activities as it would appear on the ground, three months after the territory had been liberated. They were required not only to predict the organization, staff and equipment requirements for every department of the military administration, but were instructed to analyse the legal, financial, administrative and other implications of their plan and to prepare all the draft proclamations, policy directives and departmental instructions which might be necessary to ensure an efficient working machine. At a later stage, and before the operational plan was available, consideration was given to the progressive reorganization of the military administration to ensure in due time a smooth change-over to civil government.

From the comprehensive picture thus obtained, the planners were to work backwards to the planning of a skeleton civil affairs organization to enter Malaya with the first waves of fighting troops and to act as a foundation on which to build by progressive phases until the ultimate target was achieved.

### General Organization of Military Administration

The following paragraphs will deal more particularly with the detailed planning for the Military Administration of Malaya, but it provides a fair example of the Civil Affairs planning for all British territories in the Far East.

The pre-war organization of the Civil Governments was studied closely ; fortunately many of the planners were Malayan officials who were fully familiar with the Malayan constitution. A policy of decentralization had been followed for a number of years which perpetuated the multiplicity of local governments. Singapore Island and the Settlements of Malacca, Penang and Labuan formed the Government of the Strait Settlements under a Governor and Commander-in-Chief who resided at Singapore. Four of the Malay States were federated under a Federal Government and five of the States on the Malay Peninsula together with Brunei were unfederated—each with its own State Government. In the Unfederated States, the Sultans exercised a very considerable measure of local autonomy. The Governor of the Strait Settlements was also the High Commissioner for the Malay States. This necessarily brief and incomplete picture of the pre-war constitution is sufficient to demonstrate the impracticability of restoring full civil government to the territories immediately upon liberation. The considerations mentioned in the second paragraph of this article demanded a unity of initial control which a military administration was best designed to secure in the circumstances of the case.

The general plan for the military administration was drawn up on the basis of a single government for the whole of Malaya with centralized direction. This presented the difficulty of devising a satisfactory method by which this unified military government could be progressively decentralized to the pre-war constitutional pattern in order to secure a smooth change-over to the civil authorities when the military administration terminated. Fortunately, this problem was satisfactorily solved at an early date, for the War Office was confidentially informed, early in 1944, that His Majesty's Government had decided to revise the constitution of Malaya after its liberation by forming a separate colony for Singapore Island and, in addition, a centralized government under a separate Governor on the Mainland which would embrace the Settlements of Penang and Malacca, the four Federated States and the five Unfederated States.

With this scheme in mind, it was possible to plan the organization of the military administration of Malaya on a basis closely linked to the future civil government of the country. At the H.Q. of the Military Commander, the C.C.A.O. would have a small Headquarters staff comprising mainly a secretariat, together with advisers on law, finance, Chinese affairs, technical services and public health.

It was decided to set up two main territorial divisions of the Administration, viz., Malay Peninsula and Singapore Island—each of which would be under the direction of a Deputy Chief Civil Affairs Officer who would control the necessary departments of the administration in each main division.

The two main divisions were sub-divided into regions ; nine in the Malay Peninsula and two in Singapore Island. Each region was to be placed under the charge of a Senior Civil Affairs Officer responsible directly to the Deputy Chief Civil Affairs Officer concerned for the whole of the Civil Affairs work within the Region.

## Departmental Organization

Having regard to the restricted purpose of the Military Administration, it was decided by the planners that the following departments should be established ;—

(*a*) PAN-MALAYAN—under the control of the C.C.A.O.—

(i) Labour and Immigration
(ii) Postal
(iii) Printing and Publicity
(iv) Rationing and Food Control
(v) Supplies
(vi) Trade and Industry

(*b*) MALAY PENINSULA—under the control of the D.C.A.O. (Mainland)—
- (i) General Administration*
- (ii) Agriculture and Forests
- (iii) Custodian of Property
- (iv) Electrical
- (v) Finance
- (vi) Legal and Judicial
- (vii) Police, Prisons and Fire Service
- (viii) Medical, Health and Veterinary
- (ix) Road Transport
- (x) Works
- (xi) Land, Mines and Surveys

(*c*) SINGAPORE—under the control of the D.C.C.A.O. (Singapore)—
- (i) General Administration*
- (ii) Custodian of Property
- (iii) Electrical
- (iv) Finance
- (v) Legal and Judicial
- (vi) Police, Prisons and Fire Service
- (vii) Medical, Health and Veterinary
- (viii) Road Transport
- (ix) Works.

### Administrative Policy

The planners devoted considerable time to discussing and formulating policy directives on various matters either for immediate issue, after approval, by higher authority to the planners themselves or for future issue by the C.C.A.O. when the Military Administration was set up. In this work, the assistance and advice of many government departments in London were invoked ; the most important of these directives may be referred to briefly.

The Secretary of State for War issued a general directive for Civil Affairs in Malaya to the Supreme Allied Commander. This document directed him to set up a Military Administration for the government of the civil population and instructed him to assume for himself, by proclamation, all administrative, executive, judicial and legislative powers in the territory, to suspend the powers and jurisdiction of all courts and tribunals and, in their place, to set up Military Courts which would derive their authority from his proclamation and deal with all offences committed by the civil population. It was laid down that such courts should administer the laws in force in Malaya immediately prior to the Japanese occupation, but modified, suspended or supplemented by proclamation as might be considered necessary for the security of the liberating forces and the maintenance of order. The directive also required the Supreme Commander to take full responsibility, subject to operational requirements, for the provision of supplies for the needs of the civil population and for local industries and agriculture, to a level necessary to prevent disease and unrest and to secure the maximum assistance for the progressive restoration of the territory. It was stated that it was the policy of His Majesty's Government that the administration of Malaya should be transferred to the responsibility of the Colonial Office as soon as possible and the duty to recommend when this transfer should take effect was placed upon the Supreme Allied Commander.

*Not to be confused with " administration " in military parlance. In a Civil Affairs context " administration " means the administrative task of governing a territory, including the direction and control of local councils, municipal boards, etc. and, to a large extent, the collection and disbursement of public revenue.

In addition, the Secretary of State for War issued a monetary and fiscal guide in which it was laid down that, as from the date of entry into the territory, Malayan currency only should be accepted as legal tender and that generally no notes issued by the Japanese, whether denominated in dollars or yen, should be declared as legal tender. The Supreme Allied Commander was instructed to close all banks and treasuries and to safeguard valuables, records and premises until such time as banks and similar institutions could be allowed to operate. He was required to declare a general moratorium on all pre-occupation debts. Japanese financial houses were to be closed permanently and the records of such undertakings were to be examined and a scheme for their liquidation prepared. Instructions were given regarding the re-opening of the Post Office Savings Banks and the collection of public revenue. A War Office directive was issued on the Custodianship of Property in Malaya.

Memoranda were issued on the behaviour of public servants during Japanese occupation and the procedure to be adopted in the case of those who had been disloyal ; directions were given regarding the trial and punishment of disloyal persons in Malaya who collaborated with the enemy.

As indicated above, it was appreciated in the course of planning that the Military Administration in Malaya would inevitably be forced to deal with a number of problems relating to the welfare and rehabilitation of the people which could not be postponed, though they would have no military significance whatsoever. It was thought, therefore, that the Supreme Allied Commander would require general policy directions on a number of subjects in order that any action he might feel compelled to take would, as far as possible, be in consonance with the long-term policy which the Colonial Office intended to adopt when it resumed control of the territory. Eighteen long-term policy directives were prepared by the Colonial Office in consultation with the planners and, after approval by the Secretary of State for the Colonies, they were printed for distribution to the senior officers of the Military Administration concerned in their implementation. In the light of the directions which the Supreme Commander had received, he issued a statement of policy to the officers responsible for the Military Administration and approved the comprehensive Civil Affairs plan prepared by the C.C.A.O. The salient features of the plan will be referred to in later paragraphs but it is convenient first to give a brief résumé of the Supreme Allied Commander's directions on policy.

The Supreme Allied Commander pointed out that in liberating Malaya every member of the British forces was responsible for ensuring that the peoples of the country were met and approached with understanding and sympathy in order that their confidence in British good-faith, fair dealing and impartial justice might be retained. He was particularly anxious that no persons should suffer on account of political opinions honestly held, whether then or in the past, but only on account of previous crimes against the criminal law or actions repugnant to humanity. The S.A.C. stressed the heavy responsibility which would rest upon the Civil Affairs Officers under the British Military Administration. He explained that the establishment of the British Military Administration had the effect of continuing the suspension of the constitution which had necessarily occurred at the time of the Japanese invasion, but emphasized that all existing laws should be observed and enforced as far as circumstances permitted and that the people themselves should be associated with the mechanism of government as much as possible. To this end he directed that the C.C.A.O. should inaugurate an Advisory Council for Singapore Island and another similar Council for the

Malay Peninsula with a membership which should be fully representative of the local population and of unofficial interests. He directed further that in each Civil Affairs Region in the two Divisions, the Senior Civil Affairs Officer should set up a Regional Advisory Council. The Supreme Allied Commander also directed that pre-war municipal, rural and other similar Councils, Boards or Committees should be set where practicable in an advisory capacity ; in all cases representation was to be as broad as possible and the Military Administration authorities were not to consider themselves bound by any pre-war restrictions or selections.

Special instructions were issued regarding the resettlement and rehabilitation of the Guerilla bands which had been operating against the Japanese and also with regard to the courtesies to be extended to Their Highnesses the Sultans.

## Law and Order

The establishment of the Military Administration, and the full powers which the Supreme Commander took unto himself by his Proclamation, was legally a declaration of martial law which has been defined as " no law at all but merely the will or whim of the Military Commander." It was, however, the policy to adopt and follow the established law of Malaya, so far as military exigencies permitted, and it was not, therefore, deemed politic to declare martial law as such in the first Proclamation issued by the Supreme Commander. It was the particular responsibility of the legal planning staff to devise ways and means by which the Supreme Commander could exercise all powers he needed with the greatest possible regard to the established law of the territory.

In order that existing laws could be applied as far as possible during the military period, the legal planning staff prepared a long draft Interpretation Proclamation introducing a large number of temporary amendments to the local laws to bring them into consonance with the structure of the military Civil Affairs organization (e.g., the powers of the Civil Governor were to be vested in the C.C.A.O., etc.).

The safety of the liberating forces was secured by a special Proclamation which provided the death penalty for more serious crimes and enumerated a considerable number of less heinous offences punishable with imprisonment or fine.

Much care was expended on the preparation of a Military Courts Proclamation. A Superior Court was established with criminal jurisdiction roughly analogous to that of the Supreme Court. Two types of Superior Court were provided for in the Proclamation, viz., a British Officer Court, comprising a President and two officers in the British forces, which had jurisdiction in regard to offences such as treason, treachery, sedition, looting, the laws and usages of war and offences against the forces, and an Assessor Court to deal with all other serious crimes and comprising a British President with two local inhabitants as assessors. In the case of a British Officer Court a majority verdict was required and in the case of a trial before an Assessor Court it was necessary for the President to agree with the opinion of both or at least one of the assessors. If the President disagreed with the opinion of both assessors the proceedings were stayed and a new trial was held with the aid of fresh assessors. A sentence of death by a Superior Court required the confirmation of the G.O.C. ; sentences of imprisonment exceeding four years, or fines exceeding two thousand dollars, or whipping exceeding twelve strokes, required the confirmation of the C.C.A.O.

District Courts were established for dealing with lesser offences and had a jurisdiction to impose sentences not exceeding three years imprisonment, two thousand dollar fines or whipping not exceeding ten strokes, or any combination of the above. Certain sentences required confirmation by the President of the Superior Court.

The Proclamation contained provisions authorizing the review and reduction of sentences by duly authorized officers. No appeal was allowed against any judgment, the persons aggrieved being entitled, within fourteen days, to apply by petition for review.

The C.C.A.O. was authorized to make rules of procedure to govern the proceedings in the Military Courts ; these were prepared by the legal planners.

### Finance

Financial control was exercised by the War Office by the appointment of a Controller of Finance and Accounts to the staff of the C.C.A.O. This officer prepared, during the planning period, directions on the manner in which the accounts should be kept and the method of financial control to be employed. As a general guide, the Military Administration was to base itself on the 1941 Estimates as approved for the Malayan territories by the Colonial Office prior to the Japanese invasion. Instructions were issued regarding the payment of rehabilitation grants to the locally employed staffs of the civil governments and a revised scale of payments to subordinate staffs was drawn up and approved by the War Office and Colonial Office ; arrangements were made for the supply of adequate currency and for the provision of postage stamps, over-printed " B.M.A." Instructions were also issued in regard to the re-opening of the Post Office Savings Banks and the value to be given to pre-war transactions on the one hand and transactions which occurred during the Japanese occupation on the other.

### Police, Prisons and Fire Services

It was anticipated that the police, prison and fire services would be very largely non-existent when Malaya was liberated and exhaustive plans were prepared for the re-assembly of the former members of these services and their early re-training and re-equipment. Early in 1944, a Police Training School was opened in India and the recruitment of Northern Indians was undertaken with a view to introducing into Malaya, upon its liberation, a nucleus of a trained police force.

### Road Transport

Fresh legislation was prepared for the registration and licensing of motor vehicles on a Pan-Malayan basis, and arrangements were also made for the licensing and control of public service vehicles. In addition, the planners prepared estimates of the various types of vehicles which would be required for use by the Military Administration staff, for the immediate needs of scavenging and other similar services, the Public Works Department, and for the movement within the territory of relief supplies for the civil population.

### Public Services

In conjunction with the R.E., R.E.M.E., R. Signals and transportation services, arrangements were co-ordinated for the immediate reconditioning and operation of the railways, ports and harbours, telephone, telegraph, radio, electricity, water and similar undertakings. In particular, the Civil

Affairs staff were to be responsible for the reassembly, payment and direction of the locally employed staffs of all these undertakings.

### Labour

In co-operation with Pioneers and Labour, local labour rates were devised and approved and plans were made for the recruitment of available labour and for their allocation to urgent military and civil tasks according to a settled programme of priorities.

### Supplies

The planning of the supplies programme proved a formidable task and is best dealt with in several categories.

First and foremost it was necessary to introduce into the country large quantities of foodstuffs and other necessaries for the civil population, which was known to be in desperate straits. The planners had first to secure a clear picture of the country's requirements before the war and then to calculate reliable population figures. It was eventually decided to set up a committee in London to produce comprehensive estimates of requirements in all Far Eastern territories over a period of two calendar years, divided into four successive periods of six months. It was the task of the planning staff to produce figures for Malaya and to negotiate them through the machinery of the London Committee. These requirements fell under the following heads :—

Food
Agricultural, including fishing, supplies
Medical supplies
Soap
Clothing and Footwear
Communal requirements for Refugee Camps, etc.
Individual household requirements
Newsprint

The choice of a two-year period for these estimates was dictated by the necessity to avoid any delay in the distribution of supplies when the change was made from War Office to Colonial Office control. The procurement and shipment of these supplies was undertaken by the Ministries in London but, apart from difficulties of production, the rate of flow of the supplies into the territory was dependent on the availability of shipping and the conflicting claims of strictly military material and stores.

Apart from the supplies already enumerated, which fell within the responsibility of the Supreme Allied Commander "to prevent disease and unrest," the rehabilitation of the territory, even for the purposes of the further prosecution of the war, demanded the early importation of a wide range of other supplies, for which estimates were prepared by the planning staff. These were examined and screened by another organization in London, known as the Brett Committee, which dealt with the following types of requirements :—

(*a*) Electrical
(*b*) Water supplies
(*c*) Railways
(*d*) Telecommunications
(*e*) Sewerage, sewers and refuse disposal
(*f*) Repairs to houses
(*g*) Hand-tools
(*h*) Workshop equipment
(*i*) Gas supplies
(*j*) Incinerators
(*k*) Abbattoirs
(*l*) Bridges
(*m*) Fuel (solid and liquid)
(*n*) Refrigeration
(*o*) Engineering stores
(*p*) Public service vehicles.

### Trade and Industry

Very extensive research into the problems affecting trade and industry in Malaya was undertaken by the planners and the future of the rubber and tin industries in particular absorbed a great deal of time. Detailed arrangements were made for setting up official agencies for the bulk purchase of rubber, tin, copra, palm oil and other primary products. Consideration was also given to the supply of agricultural implements and other accessories needed to revive the industries of the country.

Arrangements were made for specially selected commercial enterprises to recommence operations as soon as Malaya was liberated ; it was agreed that these enterprises should recommence their operations on a commercial basis, but that official sponsorship should be extended to enable them to secure the release of personnel from the Services or other essential occupations elsewhere, and to secure special priority for the procurement and shipment of plant, machinery and any other commodities essential to their undertakings. Special arrangements were made regarding the local distribution of supplies of petrol, oil and lubricants to the civil population and, in conjunction with the Ministry of War Transport, the planners examined the problem of re-establishing coastwise and local seaborne trade.

### Rationing and Food Control

Consideration of supply problems made it quite clear that the Military Administration would have to exercise rigid control over food and other essential commodities by rationing and other means, and extensive plans were made in this connexion. Proclamations for food control, price control and rationing were prepared and exhaustive instructions drawn up on the subject. In addition some seven million food cards and application forms were printed.

### Custodianship of Property

Considerable discussion took place as to the manner in which British, Allied, Neutral and Enemy property, whether State or private, should be handled by the Military Administration when it was established. It was evident from the outset that considerations of manpower and expense would preclude the Administration from attempting to take charge of all the estates, factories and other commercial properties, which would be abandoned by the enemy when Malaya was recovered. The method adopted to deal with the problem was to invite all the major commercial interests concerned to form Committees of Inspection, whose duty it would be, under the guidance and with the assistance of the Custodian of Property, to visit properties, make reports on their condition, and take such measures for their preservation by the appointment of caretakers and watchmen as might be feasible in the circumstances of the case. Many legal problems in connexion with the plan had to be resolved by the Chief Legal Adviser but ultimately, with the assistance of the Colonial Office, commercial interests in Malaya which had representatives in the United Kingdom, Malaya, India and Australia, were brought into the scheme and the final arrangements were settled and implemented. The directive on custodianship of property in Malaya issued by the War Office made due reference to the scheme.

### Refugees and Displaced Persons

It was agreed in the course of planning that the Civil Affairs organization would not be responsible for the repatriation of the Prisoners of War and civil internees who would be found in Malaya ; this task was to be dealt with by "*A*" Branch.

There remained, however, four main problems for which Civil Affairs planning was undertaken, viz., (*a*) the relief of destitute persons in Malaya, (*b*) the repatriation to Malaya of persons who had been deported by the Japanese to Siam and elsewhere, (*c*) the repatriation to Malaya of Malayan refugees in India and elsewhere, and (*d*) the care and ultimate repatriation of the large numbers of labourers, principally Javanese, whom the Japanese had brought into Malaya for work and who were known to be in a serious physical condition.

It was decided that the actual carrying out of these tasks would fall mainly on the Labour and General Administration Departments. A small headquarters directing staff was required and, in addition, extensive arrangements were made for the establishment of Regional Camps which would be staffed mainly by teams of relief workers, sponsored by the British Red Cross and the St. John's Ambulance Organization. These special relief units were designed to run Refugee Camps, Rural Hospitals, Infant Welfare Clinics, feeding centres and travelling dispensaries, as required. The work of relief called for bigger staffs than could be made available at the time of liberation and further assistance was received from the Australian and Indian Red Cross Organizations.

### Personnel

No other branch of planning presented a more difficult and anxious problem. On the basis of the detailed planning undertaken, it was estimated that some thousand Civil Affairs Officers would be required on the ground at the end of three months after the initial landings in Malaya. War Establishments were prepared and approved for each department of the Civil Affairs organization in the two Divisions, with corresponding War Equipment Tables. Provision was also made in the establishments for Other Rank personnel who, it was estimated, would be required in the initial stages of the Military Administration, though it was hoped that they could be largely replaced as the subordinate civil staffs of the previous governments reported for duty.

Many of the posts to be filled on the War Establishments demanded specialist qualifications and, in certain departments, it was essential, for success, to employ a proportion of Officers and Other Ranks who had previous experience of the country and its people. It may be added that the European staff of the pre-war civil governments in Malaya numbered approximately two thousand ; many of these were incarcerated in Malaya or had been killed in the course of the Japanese Campaign ; others who had escaped from Malaya were unfit to return. In the result only about 230 of the pre-war Malayan officials were available for posting to the Military Administration. Of these, some were still civilians serving in other parts of the Colonial Empire and their return to the United Kingdom and commissioning into the Army had to be arranged. Others were already serving in the Armed Forces and their reposting to the Military Administration had to be negotiated. For the rest, Army Officers had to be selected and trained for Civil Affairs duties as soon as they could be made available. Though much planning was done, in the hope that the Military Administration would take the field reasonably well staffed, this desirable result was not wholly achieved.

## Planning for the Operational Phase

As soon as the operational plan for the liberation of Malaya was disclosed to the C.C.A.O., plans were prepared for the mobilization, mounting and deployment of the Civil Affairs organization. The objective was to get parties of Civil Affairs into the territory with the leading troops and to pass in reinforcements which would establish a nucleus administration in the rear areas as the troops advanced. This called for an organization which differed entirely from the departmental organization envisaged to carry out the Military Administration when the territory as a whole was liberated.

In the operational phase, therefore, a few Civil Affairs Staff Officers were attached to the Headquarters Staffs of the Army, the two Corps and the nine Divisions which were taking part in the operation ; for each of these a War Establishment was drawn up and approved. These Staff Officers were to advise and act for their Commanders in all Civil Affairs matters during the course of the operation.

In addition, it was necessary to devise a method by which a number of Civil Affairs Officers could be introduced progressively into the liberated areas in the form of regularly organized military units. To this end, a Civil Affairs Group was approved which comprised the following :—

| | |
|---|---|
| Colonels—Civil Affairs | 6 |
| Staff Officers, C.A.—1st Grade | 17 |
| Staff Officers, C.A.—2nd Grade | 45 |
| Staff Officers, C.A.—3rd Grade | 34 |
| Staff Lieutenants, C.A. | 16 |
| Adjutant—Captain | 1 |
| Quartermaster | 1 |
| | 120 |

The functions of the officers included in each Group were varied according to the task allotted to the Group, but a certain number of officers in all the following functions were included :—

General Administration
Finance
Police, Prisons and Fire Fighting
Labour
Supplies
Medical
Legal
Works

A Group was commanded by a Group Commander and was deployed in ten detachments, each under a Detachment Commander, consisting of twelve Officers and fourteen British Other Ranks with the necessary transport, equipment and stores to make them self-contained.

In addition to three Operational Groups, other special C.A. units were created by the approval of appropriate War Establishments for the purpose of the operation. These included Police Units, each of which comprised three Officers and one hundred Other Ranks ; various types of Supply Units ; Medical Units designed to set up medical stores, general hospitals of 1,000, 600, 200 and forty beds, and three types of Hygiene Units ; Road Transport Units of various sorts and a number of technical sections comprising railway, signals, works and electrical staff. About fifty different Operational W.Es. were required for the task in view and in many instances several units of each type of establishment were mobilized.

The total number of posts provided on the operational War Establishments, referred to above, coincided with the number of posts provided in the Headquarters and Departmental War Establishments which had been drawn up first in the course of planning for the carrying out of what might be described as the static Military Administration. As soon as all the operational units had been phased into the territory and a centrally directed and co-ordinated administration was achieved, all the operational establishments were revoked and the entire staff under the C.C.A.O's. command was re-posted to the static War Establishments of the departmental organization.

## Conclusion

As stated above, planning for Malaya has been particularly referred to in this article but, in conclusion, some mention may be made of certain special features which arose in the other territories.

*Burma*

This country was never entirely occupied by the Japanese and the areas which remained in British hands were, for a time, administered by the Government of Burma which had been forced to take up residence at Simla. On 1st January, 1944, however, the Supreme Allied Commander assumed full responsibility for the Military Administration of the whole of the country and the C.C.A.O. became solely answerable to him. The Government of Burma, however, remained in being at Simla and dealt particularly with the planning for the period following the re-establishment of normal civil government. There was not, therefore, the same complete integration between the Civil Affairs organization and the future civil government as was possible in the case of Malaya.

*Siam*

The curious situation which arose in the case of Siam was that the Siamese Government had declared war on Great Britain but not upon America or any other Ally ; though theoretically at war with Siam, Great Britain had in fact maintained friendly underground contacts with individual members of the Siamese Government throughout the greater period of the Japanese occupation. There was, therefore, never any serious question of setting up a Military Government in Siam. The only Civil Affairs organization which was required comprised a small unit of Civil Affairs Officers attached to the Headquarters staff of the British Division that was sent to Bangkok to accept the Japanese surrender and to arrange for the evacuation of Allied Prisoners of War and civil internees.

*The Borneo Territories*

Planning for these proceeded on much the same lines as in the case of Malaya but there were certain differences due to the belief that, upon the restoration of civil government, the Rajah would re-establish his independent government in Sarawak and that the Chartered Company would resume sovereign authority in British North Borneo. As a matter of military convenience, it was decided to set up a single Military Administration for all Borneo territories with two main sub-divisions, each under a D.C.C.A.O. Sarawak formed one division and Brunei, British North Borneo and Labuan, the other. The recruitment of suitable staff for the Borneo Military Administration proved even more difficult than in the case of Malaya and some complications occurred by reason of the fact that the planning for the Borneo Military Administration took place in London, whereas in the event the territories were liberated by Australian Forces of the South West Pacific Command operating from Australia.

*French Indo-China*

As in the case of Siam, a small Civil Affairs element was required for attachment to the Headquarters of the British Division which was dispatched to Saigon upon the Japanese surrender.

*Hong Kong*

The general trend of Civil Affairs planning for Hong Kong was roughly identical with that of Malaya.

*Netherlands East Indies*

No mention of the Civil Affairs arrangements for the N.E.I. has yet been made. The situation was that the Dutch Government was responsible for this planning and for the provision of the necessary Dutch Civil Affairs Officers, who were to operate as a military organization under the British Commander responsible for the liberation of the Netherlands East Indies. It was intended that no British personnel should be employed except as Liaison Officers with the Dutch Civil Affairs organization. With the Japanese surrender and the spontaneous Indonesian Movement that occurred, events took a very different turn which need not be enlarged upon here.

# ARKS IN ITALY

*By* MAJOR R. L. FRANCE, M.C., R.E.

THIS article has been written to illustrate the usefulness of the ARK bridging tanks in the last year of the Italian Campaign and, in passing, to describe the snags met in using them to make rapid A.F.V. obstacle crossings under fire and how some of these were overcome.

## THE ITALIAN ARK (See Photo 1)

The ARK used was a Mk. III or IV Churchill tank hull, with turret ring opening covered with a 1 in. welded steel sheet to provide a deck flush with the tops of the tank tracks on which crossing tanks moved. Fifteen foot (Mk. I) American Metal Treadway Ramps were pivoted on welded brackets in continuation of the tank tracks and were held in place for travelling by king posts, with 2 in. S.W.R. and a quick release mechanism inside the hull. To enable jeeps to cross, a light metal plate was welded on brackets fixed on to the inside of the left-hand treadway, but this was easily damaged and restricted the view of both the tank Commander and driver. The Mk. II (wider and shorter) American Treadway was also used. Steel rail wheel-guides were welded on brackets running outside the ARK tracks. The Tank carried a No. 19 W/T Set and a hull "BESA" M.G., which were the responsibility of the wireless operator who made up the crew with the Commander and driver. One ARK unaided was able to span a gap of up to 50 ft. with total depth of 10 ft. and containing not more than 5 ft. of water.

## ORIGINAL ORGANIZATION AND EQUIPMENT

In the earlier organization (1 Assault Regt. R.A.C./R.E.), three ARKS formed a troop. This troop worked in close co-operation with the separate A.V.R.E. troop. The A.V.R.E. troop at this time was equipped with the fascine and S.B.G. assault bridge for gap crossing, "General Wade" demolition charges for rapid breaching of obstacles by hand and the "snake" explosive line charge for minefield breaching. Shermandozer tanks were operated by a separate squadron of the regiment.

## Early Operations and Lessons

The regiment moved forward just prior to the Gothic Line Battle. A long approach march and subsequent heavy going in low gear in mountain tracks was too much for most of the tanks, which had a very limited expectancy of life ; they had been salvaged off dumps in North Africa. First-class unit maintenance and good recovery arrangements by the regiment were soon found to be indispensable. Good wireless communications were quickly proved invaluable for control of squadrons which became widely dispersed. An early difficulty was the reluctance of Commanders in using an untried " new weapon." They had little opportunity in the middle of a battle to attend the demonstrations which were arranged. The important training in co-operation with prospective user formations had to be done during lulls in the battle. It soon became apparent that squadrons were best used under control of Divisional Cs. R. E. as part of the R.E. bridging plan, rather than under command of tank brigades.

Between 14th September, and Boxing Day, 1944, the two ARK and A.V.R.E. squadrons completed over thirty ARK crossings of canals and small rivers, in addition to numerous smaller crossings made using fascines and assault S.B.G. bridging aided by Shermandozers of the third squadron. Most of these crossings were made by single ARKS, sometimes on fascines, or with the help of explosives or Shermandozers. Because of mechanical unsoundness it was always necessary to plan on 100 per cent reserve tanks for any operation during this period. Most of the crossings were made under cover of darkness with artificial moonlight (when available) or the dawn mists which gave protection from A.Tk. Guns and to dismounted crews. A high standard of driving was therefore necessary to ensure the tanks were not ditched or fascines knocked off in narrow Italian lanes. Air photographs were invaluable for route planning as well as for the actual crossing recce, which sometimes had to be omitted for considerations of speed or enemy action. This omission was always a great risk to the success of the crossing.

## Crossing the Savio at Cesena (See Photo 2)

One interesting crossing during this early period was made in support of 4 (Brit.) Inf. Div. over the river Savio at Cesena. An Infantry bridgehead was formed astride the Corps axis in the town but the Divisional R.E. were unable to build a Bailey bridge as the only possible bridging site was under heavy shellfire. An ARK crossing was to be tried as an alternative, as air photographs disclosed a ford with a partly submerged tank abandoned in mid-stream. Detailed recce of this part of the river was not possible but a good view of the ford was obtained from a nearby building. A German Panther tank was seen to be submerged only to about a foot below the turret ring. The approaches were clear of obstacles and so a plan was made to try and leapfrog three or four ARKS over each other and so span the 200 ft. gap. Covering fire was to be provided by supporting tanks. The start of the operation was delayed by mines found buried in the numerous piles of rubble on the routes through the town and as there was no reserve of ARKS available a mined tank casualty could not be risked. Just before dawn the routes were cleared and the tanks moved up to the river. By using four ARKS the crossing was made possible for A.F.Vs., although the water in mid-stream was 5 ft. deep. Unfortunately one of the ramp securing pins worked loose and fell out after the first few tanks had crossed. As no more ramps were

**Photo 1.**—ARKS moving along a road in Italy, showing metal treadway ramps, supported by king-posts.



**Arks In Italy.**

**Photo 2.**—Crossing the Savio at Cesena on ARKS.
Width of water-gap, 200 ft. Depth in centre 5 ft.



**Arks In Italy. 2**

available it was decided to remove the other ramp and fill the gap formed by an anchored split fascine. This was done and the crossing continued in use by A.F.Vs. supporting 4 Div. and the Canadian Corps on the right. A second hold-up for more than twenty-four hours was next caused by the rapid rise of river flood waters, the ARK bridge soon becoming submerged. When the waters subsided the crossing was still required. The fascine which had been washed away was replaced by another and the whole bridge " built up " by the divisional R.E. with rubble-filled sandbags to make a crossing possible for wheels. One ARK was badly holed by a direct hit from a heavy calibre shell but this was soon repaired by rubble sandbags.

### Later Organization and Improvements

Early in 1945, an Armoured Engineer Brigade was formed to speed up the Po valley campaign planned for the coming spring. A second armoured engineer regiment and an R.A.C. crocodile and flail regiment were formed. The Brigade had the normal tank brigade administrative service, including a large tank workshop and special recovery organization, with a Forward Delivery Squadron. These were to prove invaluable for the rapid replacement of ARKS. The engineer squadrons were reorganized into two troops, each with three ARKS and three A.Vs. R.E., a light Scout Car and two Officers. This organization was better for control and for the very important job of reconnaisance as well as making co-operation in assault teams easier. Two troops of three Shermandozers also came into the squadron, which gave the squadron leader a more compact organization capable of being split into two self-contained teams. Mechanically sounder tanks were provided and this enabled the working reserve to be reduced to fifty per cent. The A.Vs. R.E. were equipped with the petard, which was a spigot mortar capable of firing a 26-lb hollow charge ("flying dustbin") for reduction of banks and other obstacles from the cover of the A.V.R.E. The Squadron Leader and A.V.R.E. Troop Leaders each had Sherman command gun tanks equipped with two No. 19 Sets. The Squadron Tactical Headquarters was put on an armoured basis, with a White scout-car half track fitted with two No. 19 Sets for a command vehicle. The fitters team were given an A.R.V. battery charging "slave" carrier, welding trailer and White scout cars with wireless sets. All these changes had proved essential in the earlier actions and the maintenance complications of a mixed squadron of Shermans and Churchills was eased by the increased mobility of the fitters.

The squadrons' main headquarters had an increased scale of heavy load carrying vehicles for carrying made up fascines and spare ramps. The Brigade Armoured Engineer Park Squadron organization provided a quick replenishment. Spare crews were provided and trained with the squadrons and were invaluable in shortening the considerable time taken rigging up the heavy stores ; up to 100 tons per Squadron were required before a big operation. They also acted as reliefs in peak periods in operations when tank crews were carrying out tank maintenance. These spares were cut during operations because of manpower shortages but the operations ended before the bad effects on efficiency could take hold. The squadrons went forward in good time to link up with formations and to get all the stores ready for the spring offensive across the river Senio and beyond. One armoured engineer regiment had a squadron supporting each of three assualting formations and the second armoured engineer regiment, which for lack of tanks and time had trained mainly with mobile Bailey equipment, was distributed where most likely to be required.

CROSSING THE SENIO AND THE SANTERNO (See Photo 3)

The Senio crossing proved to be interesting, as part of the 30 ft. high flood banks had to be blown away and the deep central water gap was awkward to negotiate. This gap needed a split fascine and then one ARK, to be driven down steep banks to be placed squarely on the fascines, to take another ARK on top of it. Previous reconnaissance was not possible due to enemy occupation of the floodbanks and planning beyond the approach road was done by the study of air photographs. The half squadron concerned followed up the assaulting infantry and the crocodiles at last light. After an initial delay, due to unsuitability of the immediate approaches on the spot chosen, one ARK ramped up to the first floodbank. A gap in the top of the bank was next blown with large numbers of "General Wade" charges. One A.V.R.E. then "placed" a fascine in the gap and this was split and spread by dismounted crews while an armoured bulldozer was improving the blown gap approaches. The two ARKS were then placed while the far bank was being prepared for blowing. Two blows were required, but one regiment of tanks was able to cross by dawn. The same half squadron, with replenished equipment, repeated their performance the following night over the river Santerno, which was slightly bigger and required two fascines. A Shermandozer working on the near approach ramp nearly blocked the crossing when it lost a track, but an armoured bulldozer was again available and saved the situation by making a close tank deviation round the obstruction. The need for the inclusion of this type of bulldozer in the war establishment was often apparent. Two other interesting crossings of canals a little later entailed the accurate "submerging" of ARKS in water which came over the driver's hatch. This required a very rapid "bale out"! Waterproofing and periscope arrangements would have been useful.

One squadron in the space of the three weeks rapid advance made over thirty varied assault crossings. This squadron was frequently split into two halves, operating sometimes twenty miles apart, but the new organization, with its improved specialized recovery and replenishment, made this possible. Good wireless communications facilitated rapid switching to new formations; eight such switches were made during this period. It was always preferable to work as a squadron, firstly because of the additional backing from squadron tactical headquarters with its intelligence and maintenance facilities, and secondly because of the extra control through the Squadron Leader. In the Po valley type of country with its small rivers and canals the ARK was the principle "weapon" of the Armoured R.E. and was invaluable for speeding up bridging operations and avoiding casualties. With structural improvements in size and performance and using aids for navigation, the ARK of the future is likely to be used more and more in all types of country.

## TIMBER—AND THE MEANS OF ASSESSING ITS STRENGTH AND PROPERTIES IN THE FIELD

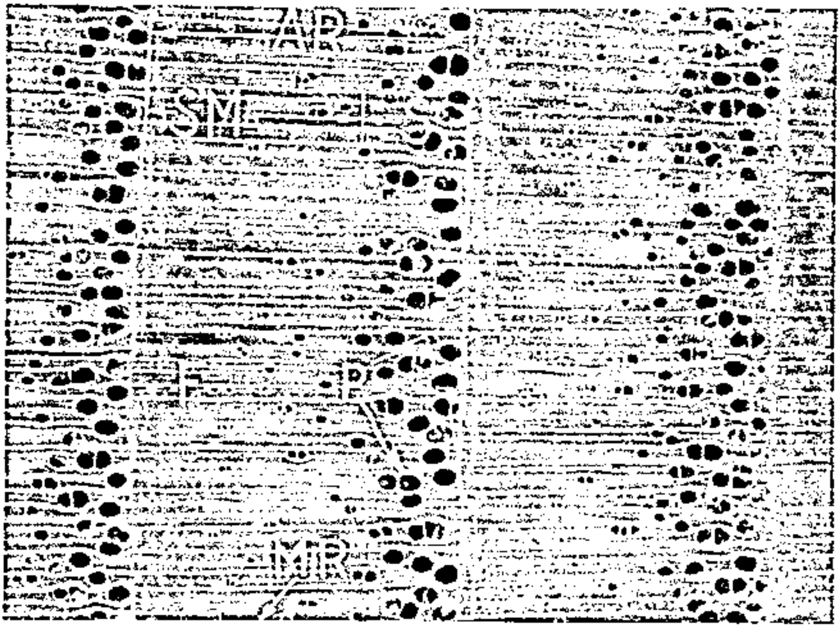



**Photo 1.**—Typical end grain surface of hardwood to a linear magnification of 10. (Specimen of Ash showing distinctive grouping of large pores in springwood zone. In many hardwoods the pores are more uniform in size and distribution throughout the annual ring.)

*For reference to letters on photos see under Figures* 1 *and* 2.

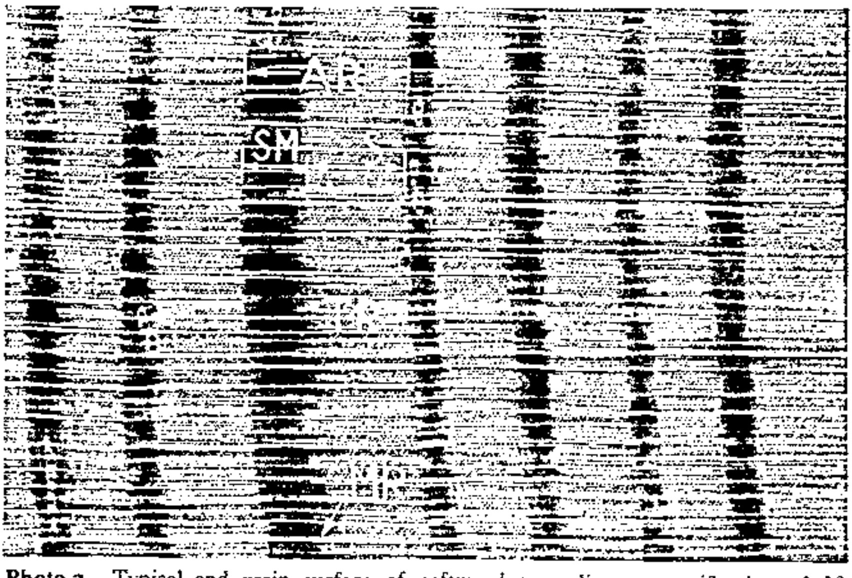



**Photo 2.**—Typical end grain surface of softwood to a linear magnification of 10. (Specimen of Douglas Fir.)

# TIMBER—AND THE MEANS OF ASSESSING ITS STRENGTH AND PROPERTIES IN THE FIELD

By Major A. G. P. Leahy, O.B.E., R.E. and R. P. Haines, A.M.I.C.E., A.M.I.Struct.E., E.-in-C. Dept., W.O.

## Introduction

It would be a mistake to assume that the usefulness of timber as a constructional material in the field is likely to diminish.

It is true that loads generally are increasing and that the military engineer will turn in the first instance to steel or reinforced concrete. But it is also true that the trend of modern developments, particularly the greatly increased destructive power of weapons resulting in wide dispersion and greater liability to interruption of communications, will impose very severe strains on the transportation systems of armies in the field. For this reason, apart altogether from possible limitations in production, military engineers will seldom obtain the tonnages of engineer stores and materials that they require, and they will consequently be forced to rely to a considerable extent on local resources.

It is probable therefore that timber will often be used as the primary constructional material in bridges, jetties, roof trusses and other structures ; if only for the reason that no other suitable material is available. Moreover in view of the increasing load classes and of the tremendous quantity of constructional work likely to be required, the greatest economy in the use of timber will be necessary. It will no longer be possible to indulge in the high factors of safety, or factors of ignorance as they really were, that could be accepted in the past.

But to ensure efficient use of timber in the field better guidance must be provided to engineer officers and N.C.Os. It will not be sufficient to rely on the experience of one's carpenters, probably limited in any case to a superficial knowledge of home grown timbers, nor to the off-chance of a timber expert being available for advice.

It was with the broad object of producing this better guidance in practical form that a working party, consisting of representatives of the War Office (E.-in-C.), M.E.X.E. (Ministry of Supply), the Forest Products Research Laboratory and the S.M.E., was formed early in 1947. The object of this paper is to outline for the general information of R.E. officers the decisions taken by this committee to achieve their aim.

## The Problem

Timber is a complex organic substance and its structure and composition differ widely according to botanical species and conditions of growth. These differences are reflected in a wide variation of strength and properties, and the problem boils down to providing the engineer in the field with practical means whereby he can accurately identify the exact species of timbers available and determine the most suitable for the job in hand by reference to data provided on the strength and other characteristics. Additionally a more hasty method of assessing the strength of timber is required where time does not permit accurate identification of the species. Guidance is also necessary in assessing the strength in terms of working stresses for design calculations. In this respect the ideal would be to assess the breaking stresses (bending, shear, compressive and crushing) of the particular piece of timber concerned, and then to apply a factor of safety suitable to the particular conditions of the job.

Fortunately there has been in recent years a great advance in the collection and collation of data regarding mechanical and other properties of different species of timber. As regards strength, a great many tests have been carried out in the timber research laboratories resulting in lists of average breaking stresses for different species of timber. As regards other properties much progress has been made in collating the accumulated experience of users from all over the world, and data is now available to give useful guidance in respect of toughness, bendability, workability and durability of most species of timber we are likely to meet.

The solution of the problem is to be found in the translation of these laboratory records into practical guidance in the field.

### Conversion of Laboratory Stresses to Working Stresses

The lists of average breaking stresses of the different species of timber, as published by the research laboratories, are compiled from the results of large numbers of tests of defect-free samples of each species. They are produced with the primary object of providing comparisons in strength, and therefore the figures require scaling down before they can be used as minimum breaking stresses in the field. The factors concerned are the seasoning factor, the growth factor and the defect factor.

*The seasoning factor.*—Timber in its natural state contains water which may exceed 100 per cent of the actual weight of wood substance. Most of this is free water filling the cell cavities, but some 25–30 per cent is water absorbed by the wood substance itself. The process of seasoning consists in first driving out the free water and then in reducing the content of absorbed water. The latter process causes shrinkage of the wood substance and is accompanied by a considerable increase in strength. For example, home-grown oak has an average breaking fibre stress of 8,100 lb./sq. in. in the green state at 89 per cent water content, increasing to 13,300 lb./sq. in. when air dried to 12 per cent moisture content. In the field timber will usually be used in the green state. Even if seasoned stocks are available, the probability is that the structure into which they are incorporated will be exposed to atmospheric conditions. Consequently the timber may re-absorb moisture and revert to the green state in so far as strength is concerned. Therefore, for our purposes, we must altogether neglect the higher " air-dried " stresses, and base our figures upon the lower " green " stresses.

*The growth factor.*—The strength of timber of any given species varies with the conditions of growth of the particular tree from which it comes. This variation, however, seldom exceeds $\pm$ 20 per cent of the average breaking stresses of defect-free samples of the species. We must, therefore, reduce the average laboratory breaking stresses of each species by 20 per cent to ensure that the weaker samples are not overvalued.

*The defect factor.*—Laboratory stress figures are derived from defect-free samples. In the field it would be quite impracticable to insist on a similar standard of quality. As a general rule it may be taken that a further 30 per cent reduction on the laboratory figure for bending, shear and crushing, and 20 per cent for compression parallel to the grain will be sufficient to cover all but the most obvious defects and allow for timber of good structural quality.

We have thus arrived at the situation when each species of timber may be allotted values for the minimum breaking stresses applicable to good quality structural timber, which will be 50 per cent in the case of bending, shear and crushing and 40 per cent in the case of compression parallel to the grain, below the average breaking stresses of defect-free samples as determined by laboratory tests. For the sake of brevity these minimum breaking stresses will be referred to as M.B.S. hereafter.

The defect or condition factors which affect the strength are large knots or knot clusters (because they interrupt the continuous run of the fibres) ; irregular or sloping grain ; decay ; and longitudinal splits. These defects have little or no effect when the timber is in a natural log form, but in cut scantlings the timber may be seriously weakened by the presence of irregular grain or by knots, if they occur in a length of scantling subject to maximum stress. The incidence of wane, shakes and checks, unless of such size as obviously to weaken the section, can be ignored as the former indicates the desirable feature of a grain which is parallel to the length, and the latter that some degree of seasoning has taken place.

Knots are the biggest single factor which determine the quality of a scantling. In appendix A is given the rough rules that will be laid down for the guidance of users in helping them to assess increase or decrease factors for application to the M.B.S. These rules permit a maximum increase of 1·2 × M.B.S., such as would be applicable to sound timber in log form or select straight grained scantlings with knots less than $\frac{1}{8}$ of the breadth or depth, and indicate suitable decrease factors for poor quality pieces such as 0·5 for scantlings with extreme irregular grain. It is emphasized that these rules are for guidance only. It must be left to the common sense of the user to decide whether he is justified in increasing the M.B.S. for particularly good timber, whether he must reduce it for particularly bad timber, or whether he leaves it alone as he probably will in the great majority of cases. It will be appreciated that any attempt to lay down more precise guidance will become overcomplicated for field use. Normally timber of obvious poor quality will be rejected, but in cases where timber is *in situ* in an existing structure it will have to be accepted and an appropriate reduction factor applied. In certain cases scantlings of a structure may be inaccessible and inspection impossible, and the engineer must use his discretion.

In order finally to convert the M.B.S. into working stresses, the user must ask himself two questions. First—" Can I increase the M.B.S. on account of the fact that the timber I am going to use is of select quality (as opposed to average), or must I reduce it on account of particularly poor quality ? " And second—" What factor of safety must I apply ? "

*Safety factor.*—The M.B.S., corrected by a condition factor if applicable, is as close as we can get to the probable breaking stresses of the timber with which we may be concerned. We have allowed for possible variations from the average in the conditions of growth. We have allowed for defects. But a further allowance is required to cover accidental eccentricities due to non-straightness of logs or scantlings and maldistribution of loads between components of a structure which may give rise to secondary stresses not normally calculated. Therefore a minimum factor of safety of $1\frac{1}{2}$ must be applied to convert the corrected M.B.S. into a safe working stress. In certain circumstances it may be desirable to increase the factor of safety to 2 or even higher ; as for example in the case of a semi-permanent bridge to be built to carry a high volume of traffic over a prolonged period. But this is a matter for the good sense of the engineer on the spot.

We have thus evolved a system of converting the average breaking stresses of a species, as determined by laboratory tests, into field working stresses in three moves:—

(*a*) Obtain the M.B.S. (minimum breaking stress of average quality timber) by taking 50 per cent (or 60 per cent in the case of compression parallel to the grain) of the laboratory average breaking stress of defect free green timber.

(*b*) Obtain the corrected M.B.S. by multiplying by a condition factor (up to 1·2 for superior quality timber, down to 0·5 for poor quality).

(*c*) Obtain the safe working stresses by dividing the corrected M.B.S. by a factor of safety (normally 1·5 for operational conditions but may be more at the discretion of the designer).

The answer so obtained does not entirely eliminate the possibilities of failure. For example the particular piece of timber might be the result of growth conditions giving a greater reduction than 20 per cent of the average strength of the species, or it might contain defects unnoticed by the user bringing the strength down below the corrected M.B.S. figure. But such instances will be rare enough to be accepted as justifiable military risks, though perhaps not acceptable to civil standards. The figures compare favourably with those in use in the past. For example take the case of home-grown oak in bending:—

| | |
|---|---|
| Average lab. stress for green timber .. | 8,100 lb./sq. in. |
| M.B.S. .. .. .. .. .. | 4,050 lb./ sq. in. |
| Corrected M.B.S. (assuming superior quality timber) .. .. .. .. .. | $4{,}050 \times 1{\cdot}2$ lb./sq. in. |
| Working stress .. .. .. .. | $4{,}050 \times \frac{1{\cdot}2}{1{\cdot}5}$ lb./sq. in. |
| | = 3,240 lb./sq. in. |

This figure is much more realistic than the 1,800 lb./sq. in. applicable to group I timber (including oak) in the present manuals.

### Identification

But the practical application of this system of stress values depends on the ability of the user to identify the species of timber which he is to use.

It would not be sufficient, even if it were practicable, to rely on correct recognition of the general appearance or leaf structure of the tree, because the timber in question may already be in the form of scantlings or incorporated in a structure. The solution is provided by the lens card key system of timber identification originated by the Forest Products Research Laboratory at Princes Risborough.

In this system a box of cards is provided covering the commoner species of timbers in a zone. Each species has a separate card, on one side of which is recorded the identification features and on the other the properties and strength data.

The system of identification is based on the characteristic appearance through a lens of the cellular structure of hardwood timbers. A hardwood (using the term in its botanical sense to denote timber from broad leaved trees as opposed to coniferous trees which produce softwoods) is made up of three types of wood cells; vessels for conduction of sap, storage cells in the form of rays and soft tissue, and fibres for strength. The appearance of the structure formed by these cells varies in different species of timber. Thus the vessels, which appear as holes in the end surface, vary in size and pattern; the rays vary in width and spacing; and the soft tissue appears in different characteristic forms or may be absent altogether. It is possible to draw up a key of identification features, visible through a lens of magnification 10, some but not all of which will be discernible in each species of hardwood. These standard features are printed on "Paramount" perforated card, as shown in Appendix B. (p. 129). Each feature, which is given a standard number, is related to one of the perforated holes on the edge of the card. The system works as follows :—

(*a*) A card is prepared for each species of timber with which the prospective user may be interested. Preparation consists in notching or clipping out the holes opposite to those particular features applicable to the particular species for which the card is labelled. The user is thus issued with a pack of notched cards covering all the timbers he is likely to meet, together with a knitting needle, a lens (mag. × 10), a scale (for measuring the size of vessels and rays), and a sharp knife or razor blade.

(*b*) The user obtains a small sample, match box size would do, of the timber he is trying to identify, and exposes a small portion of the end surface by making a clean cut with his knife or razor blade. He examines the end surface through the lens and notes the features visible in order of prominence.

(*c*) The user then takes up the pack of cards and inserts the needle through the hole relative to the most obvious feature which he has recognised. He shakes the pack on the needle, whereupon all cards notched for that particular feature drop out. The cards remaining on the needle have been eliminated from the search and are put on one side. The remainder are gathered up and reformed into a reduced pack. The process is repeated feature by feature until an identification is made.

Normally four or five sortings will suffice to secure an identification. On the back of the card will be recorded the data which the user is in search of. The form in which it will be presented is shown in Appendix C. (p. 130). There will be included the minimum breaking stresses (M.B.S.), suitable uses indicated by notchings, and evidence regarding bendability and durability ; in fact "form at a glance" in respect of that particular species of timber.

The card key identification equipment provides, therefore, not only the means of identifying species, but also a card index of strength and properties. The most suitable timber for a particular purpose can also be selected by inserting the needle opposite the labelled physical characteristics required.

Space does not permit of any further elaboration of the system. The equipment will of course include an illustrated glossary of terms and working instructions, but attendance at a short course will be necessary for users to acquire reasonable proficiency. One day's instruction followed by three or four days intensive practice with a set of cards and a matching set of labelled samples should suffice for the average R.E. officer. The art of identification may be compared with the interpretation of air photographs. Some features are easy enough to recognize, others require a trained eye. But it is remarkable how quickly one can obtain satisfactory results with intensive practice.

The equipment will probably be issued on a scale down to R.E. Lieut.-Colonels' commands plus certain selected units such as forestry companies. Cards will be made up into sets on a regional basis, each set covering all timbers likely to be found in the zone plus the common timbers normally imported from elsewhere.

The card key system thus provides the practical means of translating the results of laboratory research and accumulated experience into guidance for military engineers in the field. But the system has certain disadvantages.

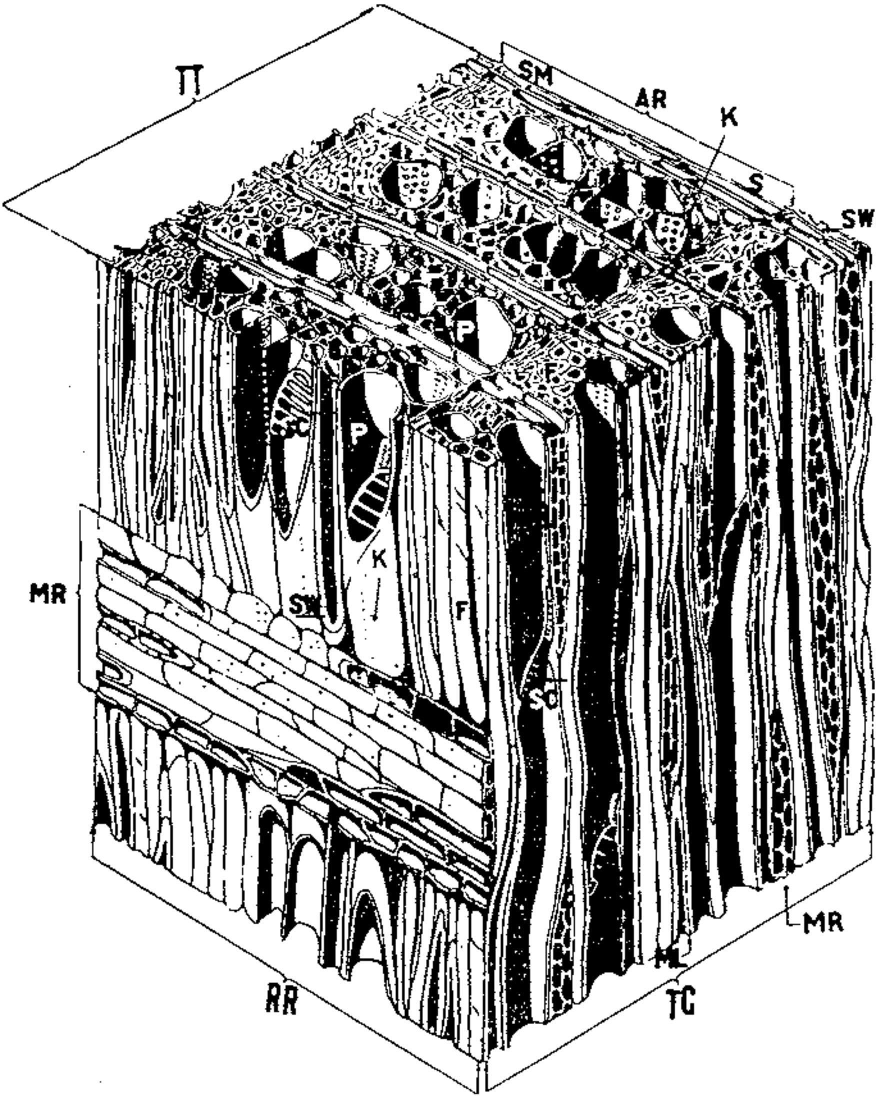



Fig. 1.—Cellular Structure of a Hardwood.

The drawings, Figs. 1 and 2, prepared by the Forest Products Research Laboratory, Madison, U.S.A., and reproduced by the courtesy of the Timber Development Association, Ltd., illustrate the cell structure of timber and represent magnification of blocks of 1/32 in. high.

The top of the block, plane TT, represents a plane parallel to the top surface of the stump or the end surface of a log. The plane RR corresponds to a surface parallel to the radius of the log.

AR The Annual Ring is the growth of one year and includes springwood and summerwood. Except in most tropical timbers, the rings are usually sharply defined and distinguishable from the growth of the previous or following years.

(continued on next page)

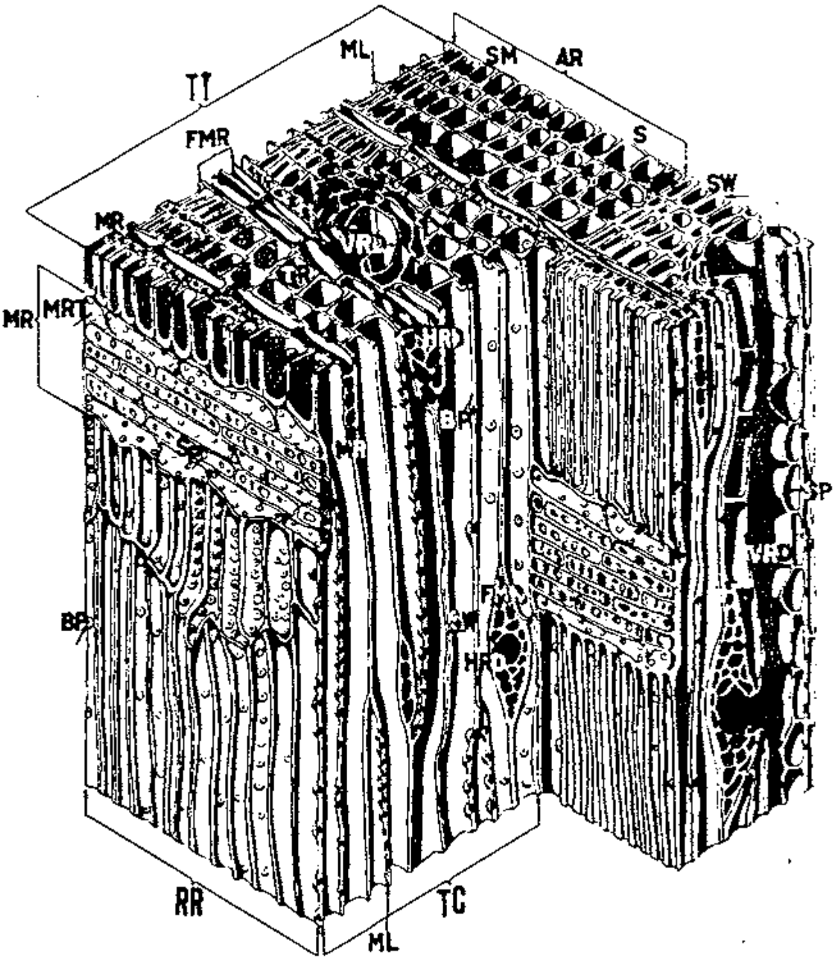



Fig. 2.—Cellular Structure of a Softwood.

(continued from previous page)

S Springwood is usually more porous than that formed later in the year and is distinguishable by its more open texture.

SM Summerwood is closer textured and denser than springwood.

P Large vessels for conducting the sap in hardwoods.

F Small cells or wood fibres which are the strength-giving element in hardwoods.

TR Tracheids or water carriers, the walls of which form the bulk of the wood substance in softwoods.

MR Medullary Rays are strips of short horizontal cells extending in a radial direction and serve to store food and distribute it horizontally.

ML Middle Lamella is a thin layer cementing together all the cells in the wood.

Firstly it does not provide a sure means of identifying the different species of softwoods, due to the more regular cellular structure of softwoods as compared with hardwoods. Secondly the user may run up against a species of timber for which laboratory data in regard to stress values is incomplete, or in respect of which no card has been provided in his pack—although this could soon be remedied. Thirdly the user may not have the time to obtain and operate the identification equipment (or alternatively send back a sample to the nearest holder of the equipment) before being required to commit himself regarding the strength of the timber concerned.

There is a need, therefore, for a simple quick method of assessing strength values to supplement the card key system. The answer lies in the fact that, generally speaking, the strength of timber varies with its hardness.

## The Field Hardness Test

It is proposed to provide a small mechanical device capable of measuring the hardness of timber and by this means enabling a reasonable assessment of its strength properties to be determined.

From preliminary investigations, it is anticipated that a simple device, which measures either the depth of penetration of a multi-point needle under a constant load or blow, or the number of blows for a standard depth of penetration, can be evolved and calibrated to record stress groups.

An essential preliminary to the adoption of such an instrument is to recast the stress groups so that each group covers a definite range of hardness values and is related to a corresponding set of minimum breaking stress figures. It has been decided to have five groups to cover the whole range of timbers from the softest (hardness value 250 lb.) to the hardest (hardness value 2,450 lb.) These hardness values are a measure of the comparative hardness of different species, being the average resistance offered by the timber to indentation to a given depth by a standard steel ball. The mechanical device should thus be capable of recording the hardness with sufficient accuracy to enable the timber to be placed in one of the five groups. Suitable values for the minimum breaking stresses for average quality timber (M.B.S.) have been adopted for each range. The table below shows the method of evolution of these figures.

| Group | Selected Hardness Range | Approx. Range of Average Breaking Fibre Stresses | Adopted Av. Br. Fibre Stress in Bending for Gp. | Minimum Breaking Stresses (M.B.S.) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Bending | Compression Parallel to Grain | Shear Parallel to Grain | Crushing at right angles to Grain | Mod. of Elasticity E. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Special | 2,450–1,850 | 19,000–15,000 | 15,000 | 7,500 | 4,500 | 870 | 1,730 | 2,000,000 |
| I | 1,850–1,350 | 15,000–11,000 | 11,000 | 5,500 | 3,000 | 690 | 1,275 | 1,600,000 |
| II | 1,350–770 | 11,000–8,500 | 8,500 | 4,250 | 2,250 | 550 | 950 | 1,400,000 |
| III | 770–510 | 8,500–6,500 | 6,500 | 3,250 | 1,740 | 420 | 750 | 1,200,000 |
| IV | 510–250 | 6,500–4,500 | 4,500 | 2,250 | 1,110 | 330 | 520 | 1,100,000 |

*Notes*

(*a*) Column 3 gives the range of average breaking fibre stresses for clear specimens applicable to the hardness range in column 2. In each group there will be a few timbers with average stresses outside the selected range, but unless the whole group is to be depressed to a lower stress value to meet these one or two outside cases, the inclusion of some weaker types must be accepted.

(*b*) Column 5. This is 50 per cent of column 4, i.e., the M.B.S.

(*c*) Columns 6–8. These figures are derived by taking fixed percentages deduced from the laboratory test results for timbers stressed in this way which show that compression and shear values bear a fairly constant relation to bending stress values.

The development of the proposed timber penetration instrument is still in the experimental stage. Preliminary tests indicate that, provided the mean of at least three readings is taken on two planes on the side grain, an instrument of this type is likely to be able to place the majority of timbers in their correct strength groups although it may be that a lesser number of groups than the five proposed will have to be accepted for identification by this means. There will be misfits and it is too early as yet to forecast in what sort of proportion they will stand to correct results. But there is every reason to hope that the instrument will provide a valuable rough and ready guide towards the rapid assessment of the strength of timber in the field when precise identification of the species is not possible, or is difficult as in the case of softwoods.

It is emphasized that the instrument can only be expected to produce a rough result. In the first place the graph of hardness plotted against strength does not produce a dead straight line and local hard or soft spots may influence the results. Also the use of stress values related to groups must essentially be less economic than when related to single species since in each case the values for the poorer species of each group have had to be used in fixing the M.B.S. for the group.

Since such an instrument will record the probable strength of the timber in the condition tested, some allowance for the degree of seasoning attained, in the case of timbers in stacks, must be made. Otherwise, when the timber is *in situ* its working stress will have been assessed too high, if the structure is exposed to moisture such as to cause the timber to revert to the green condition.

Therefore the card key system will still provide the best data and the hardness gauge will be available to fill in the gaps when, for one reason or another, it is impracticable to use the former system.

## Conclusions

Action is now being taken to implement the decisions outlined above and provide the card key identification equipment and to develop the hardness gauges, but some little time will necessarily elapse before the equipment becomes a general issue.

Perhaps the greatest advantage that can be claimed for the new proposals is that for the first time the means is offered whereby reasonable stresses can be assessed for the stronger species of timber, particularly tropical hardwoods, for which previously no stress group existed.

The attempt has been made to strike a reasonable balance between the conflicting claims of accuracy and simplicity. In the result it is hoped that the "factor of ignorance," whilst being by no means eliminated, will at least be substantially reduced as compared with what it has been in the past.

## APPENDIX A

Condition Factors.—Rough rules for assessment of increase or decrease factors for application to minimum breaking stresses (M.B.S.) in respect of superior or poor quality timber.

1. *Multiplication Factors.*—Knots are the biggest single factor in assessing the strength capability of timber, and providing the timber is sound and with reasonably straight and parallel grain from end to end the following multiplication factors for superior quality timber can be applied :—

| Knot size | Factor |
|---|---|
| ¼ b or d | 1 |
| ⅕ b or d | 1·1 |
| ⅛ b or d | 1·2 |

(b is the breadth or edge dimension and d is the depth of the scantling.)

*Notes*

(*a*) All knots in beams within ¼ of the depth from the edge, to be measured as a proportion of the edge dimension.

(*b*) Larger knots are admissible provided they do not occur in the length of the scantling subject to maximum stresses.

2. For round timber logs the factor 1·2 may be used.

3. *Reduction Factors.*—No rigid rules can be applied, but the following extreme cases are given as a guide :—

(*a*) Knots in the portion of a member subject to full stress of size approximating to ½ b or d :—
Factor 0·6.

(*b*) Extreme irregular grain :—
Factor 0·50.

(*c*) Continuous longitudinal splits on neutral axis of a beam :—
Factor 0·65.

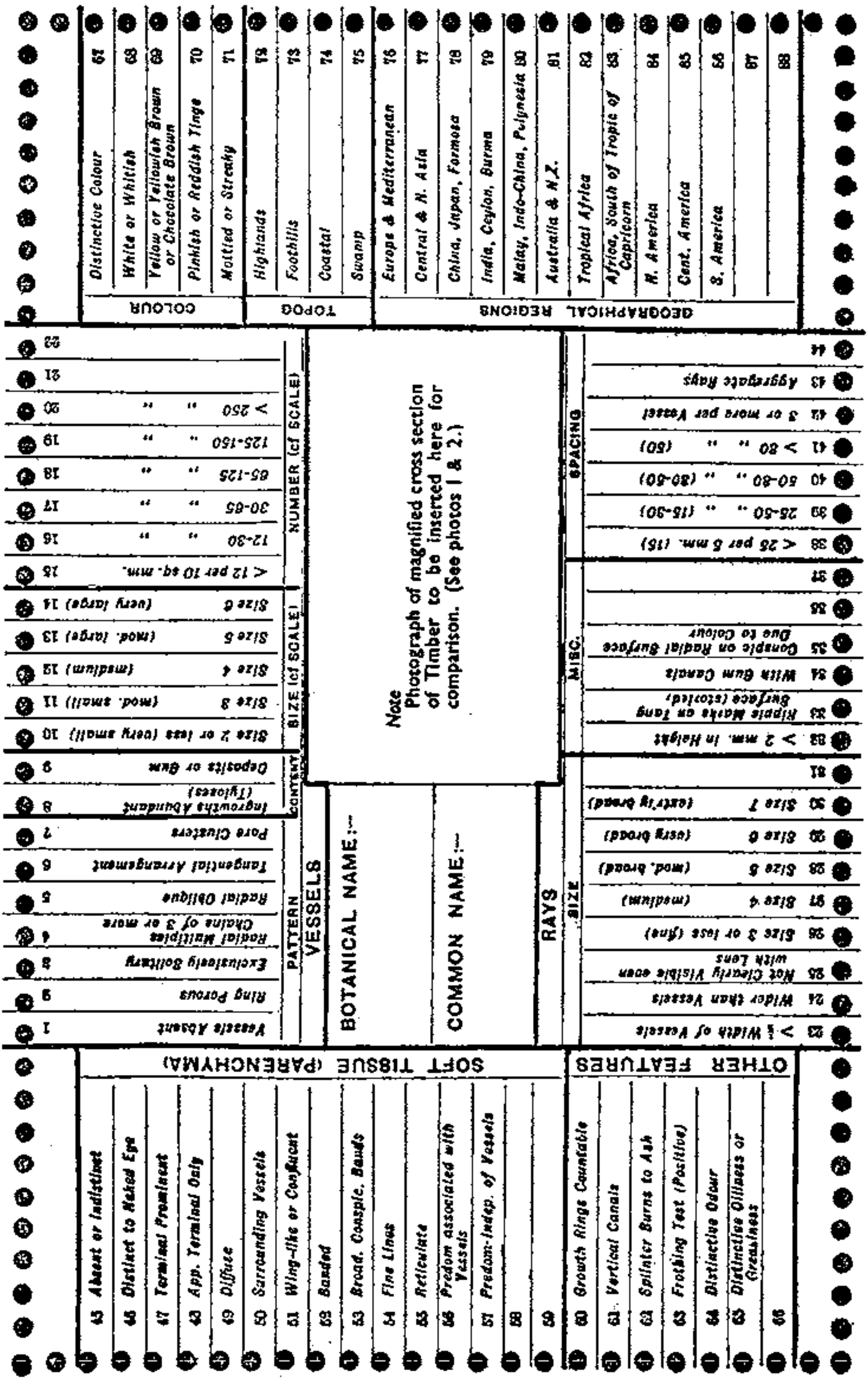
4. The effect of decay on the strength of a scantling must be estimated by assessing the penetration of the decay by prodding with a knife, and calculating the strength of the member on the residual sound section.

5. With reference to para. 3 above, reduction factors on account of (*a*) and (*b*) do not apply to shear and factors on account of (*a*), (*b*) and (*c*) do not apply to compression at right angles to the grain.

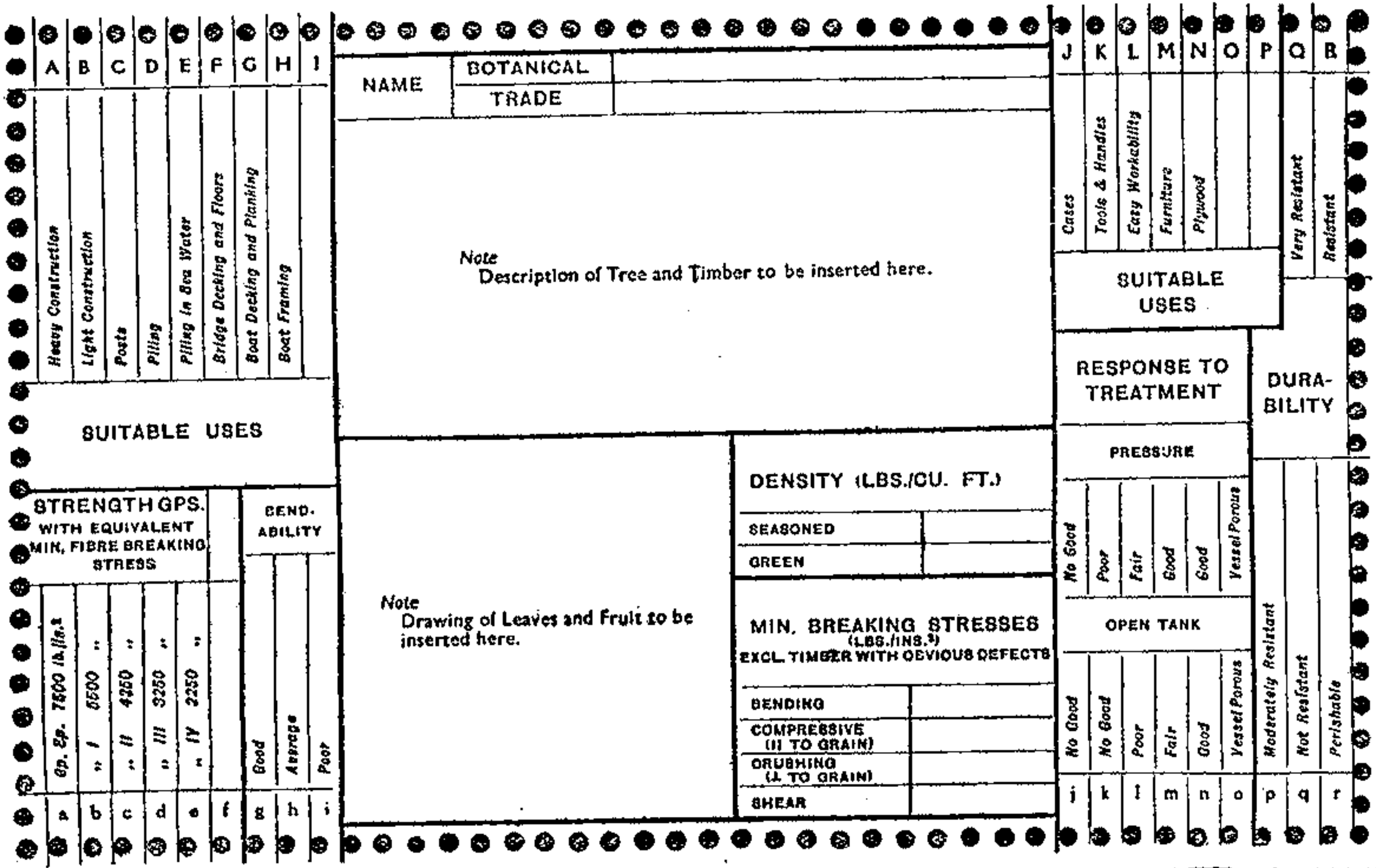
6. The modulus of elasticity is unaffected by condition factors.

7. Timber stress grouped by the hardness gauge which is seasoned but which may be exposed to moisture when *in situ* :—
Factor 0·60.

APPENDIX B


COLOUR
67 Distinctive Colour
68 White or Whitish
69 Yellow or Yellowish Brown or Chocolate Brown
70 Pinkish or Reddish Tinge
71 Mottled or Streaky
TOPOG
72 Highlands
73 Foothills
74 Coastal
75 Swamp
GEOGRAPHICAL REGIONS
76 Europe & Mediterranean
77 Central & N. Asia
78 China, Japan, Formosa
79 India, Ceylon, Burma
80 Malay, Indo-China, Polynesia
81 Australia & N.Z.
82 Tropical Africa
83 Africa, South of Tropic of Capricorn
84 N. America
85 Cent. America
86 S. America
87
88
VESSELS
PATTERN
1 Vessels Absent
2 Ring Porous
3 Exclusively Solitary
4 Radial Multiples Chains of 3 or more
5 Radial Oblique
6 Tangential Arrangement
7 Pore Clusters
CONTENT
8 Ingrowths Abundant (Tyloses)
9 Deposits or Gum
SIZE (cf SCALE)
10 Size 2 or less (very small)
11 Size 3 (mod. small)
12 Size 4 (medium)
13 Size 5 (mod. large)
14 Size 6 (very large)
NUMBER (cf SCALE)
15 < 12 per 10 sq. mm.
16 12-30 " "
17 30-65 " "
18 65-125 " "
19 125-150 " "
20 > 250 " "
21
22
Note
Photograph of magnified cross section of Timber to be inserted here for comparison. (See photos 1 & 2.)
BOTANICAL NAME:—
COMMON NAME:—
RAYS
SIZE
23 > ½ Width of Vessels
24 Wider than Vessels
25 Not Clearly Visible even with Lens
26 Size 3 or less (fine)
27 Size 4 (medium)
28 Size 5 (mod. broad)
29 Size 6 (very broad)
30 Size 7 (extra broad)
31
MISC.
32 > 2 mm. in Height
33 Ripple Marks on Tang Surface (storied)
34 With Gum Canals
35 Conspic on Radial Surface Due to Colour
36
37
SPACING
38 < 25 per 5 mm. (15)
39 25-50 " " (15-30)
40 50-80 " " (30-50)
41 > 80 " " (50)
42 3 or more per Vessel
43 Aggregate Rays
44
SOFT TISSUE (PARENCHYMA)
45 Absent or Indistinct
46 Distinct to Naked Eye
47 Terminal Prominent
48 App. Terminal Only
49 Diffuse
50 Surrounding Vessels
51 Wing-like or Confluent
52 Banded
53 Broad. Conspic. Bands
54 Fine Lines
55 Reticulate
56 Predom associated with Vessels
57 Predom-Indep. of Vessels
58
59
OTHER FEATURES
60 Growth Rings Countable
61 Vertical Canals
62 Splinter Burns to Ash
63 Frothing Test (Positive)
64 Distinctive Odour
65 Distinctive Oiliness or Greasiness
66

APPENDIX C


A B C D E F G H I
Heavy Construction
Light Construction
Posts
Piling
Piling in Sea Water
Bridge Decking and Floors
Boat Decking and Planking
Boat Framing
SUITABLE USES
STRENGTH GPS.
WITH EQUIVALENT
MIN. FIBRE BREAKING
STRESS
Sp. Sp. 7500 lb./in.²
„ I 5500 „
„ II 4250 „
„ III 3250 „
„ IV 2250 „
BEND-
ABILITY
Good
Average
Poor
a b c d e f g h i
NAME
BOTANICAL
TRADE
Note
Description of Tree and Timber to be inserted here.
Note
Drawing of Leaves and Fruit to be inserted here.
DENSITY (LBS./CU. FT.)
SEASONED
GREEN
MIN. BREAKING STRESSES
(LBS./INS.²)
EXCL. TIMBER WITH OBVIOUS DEFECTS
BENDING
COMPRESSIVE
(II TO GRAIN)
CRUSHING
(⊥ TO GRAIN)
SHEAR
J K L M N O P Q R
Cases
Tools & Handles
Easy Workability
Furniture
Plywood
SUITABLE
USES
Very Resistant
Resistant
RESPONSE TO
TREATMENT
DURA-
BILITY
PRESSURE
No Good
Poor
Fair
Good
Good
Vessel Porous
OPEN TANK
No Good
No Good
Poor
Fair
Good
Vessel Porous
Moderately Resistant
Not Resistant
Perishable
j k l m n o p q r

## ADVANCES IN WELDING METHODS AND EQUIPMENT

" ANONYMOUS "

### ATOMIC HYDROGEN WELDING

1. Experiments in the early part of this century showed that hydrogen dissociates very rapidly between temperatures of 2,600°C. to 5,000°C. If a stream of molecular hydrogen is therefore passed through an electric arc, a stream of atomic hydrogen will result, with a temperature 750°C. in excess of an oxy-acetylene flame. Reassociation, with consequent release of energy in the form of heat, takes place only in contact with a catalyst. Applied to welding, the metal acts as a catalyst, and reassociation, with the release of heat, takes place at the weld. The rate of heat transfer depends on the rate of reassociation, while the amount of heat transferred depends on the weight of gas present. For a given flame therefore the heat transference is relatively constant, it is not dependent on the relative temperatures of flame and weld as is the case in oxy-acetylene welding. Rate of heat transfer is high, with the qualification that should metal temperature reach 2,600°C., reassociation stops. Consequent on the high rate of heat transfer, and high operating temperature, a relatively small flame is required ; heating is localized, distortion reduced, while the presence of a reducing envelope of molecular hydrogen has obvious advantages.

2. Practical equipment for atomic hydrogen welding has been developed commercially. It includes an A.C. welding transformer supply, with an open-circuit voltage of 300 volts, and a current range up to 350 amp., a holder or torch for the electrodes, which are Tungsten (in view of the high heat) and a hydrogen supply. A.C. power, is used as current control is simpler, the electrodes are consumed equally and efficiency is higher.

3. Quality of the weld. Although it would be expected that a high quantity of hydrogen would be absorbed in the weld, leading to embrittlement, analysis shows that percentage absorption is similar to oxy-acetylene and arc welding. Absorption of nitrogen and oxygen is lower even than in oxy-acetylene welding. Due to the formation of hydrocarbons, carbon content may be reduced up to 50 per cent ; to circumvent this, high carbon content filler rods are used, e.g., a ·9 per cent carbon filler rod is used to produce a weld containing ·4 per cent carbon.

4. By the use of suitable filler rods, a weld in an alloy steel can be produced of similar composition to the parent metal, as recovery of the alloying elements is very high. As an example, 3½ per cent nickel steel, suitably heat treated gave an ultimate tensile stress of 84 ton/sq. in., while a butt weld in this steel, similarly heat treated gave 82·8 tons/sq. in. Ferrous alloys, with high alloy content can all be welded, while the hydrogen shield makes this technique very suitable for working with stainless steel.

5. The welding by this process of aluminium alloys has not yet been fully investigated, but such tests as have been made show that the welds are sound and free from porosity ; as in oxy-acetylene welding, a flux is needed to reduce the oxide. Monel and nickel can be satisfactorily welded, as can brass and bronze if zinc content is below forty per cent.

6. Speed of welding with this method lies between arc and oxy-acetylene welding. Costs overall compare favourably with oxy-acetylene, but Atomic hydrogen welding becomes uneconomical compared with arc welding over ⅛ in. The great advantages of this method lie in welding material too thin for arc welding (below $\frac{1}{16}$ in.) or where particularly strong ductile welds are required.

7. Examples of use to date include :—

Stainless steel beer barrels, and jerricans.
High pressure aircraft accumulator bottles (up to 2,900-lb. test pressure).
Punches and dies, on which tool steel is deposited.
Repair of worn and broken tool steels, drills etc.

## Oxy-Arc Cutting

8. The subject of lance-cutting was covered in R.E.T.M. No. 22. To recapitulate briefly, this method of cutting or boring very large blocks of cast-iron, is carried out by first pre-heating the selected starting point by oxy-acetylene, and then supplying oxygen through a thin metal tube at a sufficient pace to ensure burning and removal of molten mass by blast.

9. The present development under consideration substitutes an electric arc for purposes of heating, while the oxygen blast is delivered through coated hollow mild steel electrodes. A special gun is employed containing a trigger to control oxygen flow ; the arc is first struck and then moved to the start of the cut, at this point the oxygen trigger valve is opened and cutting starts. Due to the great heat of the arc, pre-heating time is negligible.

10. The great advantage of this method is that it can be used to cut oxidation resistant materials as stainless steel, aluminium, bronze, cupro-nickel, and nickel alloys, as well as cast iron, and steel of all kinds. In mild steel, cutting is up to three or four times the speed of normal oxy-acetylene, although costs are similar ; the cut is not quite as clean but due to the speed of cut, and high localized heat, distortion is less, and the heat affected zone much reduced. Oxygen consumption is only fifty to sixty per cent of that required for oxy-acetylene, and the gas is only consumed while cutting is taking place. Required amperages are within the capacity of normal single operator sets. No special skill is required to use this method for cutting or hole piercing.

## Contact Welding

11. Contact welding electrodes have been developed to make possible the deposition by unskilled operators of sound welds of neat appearance in downhand, vertical and overhead positions. This has been achieved by the provision of suitable coatings for the electrodes, which not only permit of continuous touch welding, but also assist the worker in starting a weld accurately, in that the arc is struck as the tip of the rod touches the work. The flux tends to peel itself off the weld, which saves time in cleaning if a second run is to be made.

12. Two types of electrode have been produced :—

(*a*) Suitable for medium penetration, neat welds, requiring from 120–230 amps., varying with plate thickness of $\frac{1}{8}$ in. to $\frac{1}{2}$ in.

(*b*) Suitable for heavier penetration welds of less neat appearance, requiring from 160–200 amps. for plate thickness of $\frac{1}{4}$ in. to $\frac{1}{2}$ in.

Methods of use differ slightly, but all positions of welding can be covered by the use of one or other of the two types. A light contact pressure only is required to maintain the weld.

13. Both types of electrode have been satisfactorily tried out on a wide variety of work from large and small butt and fillet welds to the building up of worn parts. The following conclusions have been reached :—

Welds are mechanically sound, with a good section of penetration.
Welding speed is increased, with consequent lessening of distortion.
Time for instruction is less.

Mass production, where long welds are needed, is a field of particular use for the contact electrode.

The possibility of the adoption of this type of electrode for Army use is being investigated.

## Stud Welding

14. A portable machine for stud welding is in production in the U.K. Such a method has advantages over drilling and tapping in both speed, cost and in that it does not require perforation of the plate.

15. The equipment for this welding is made in three sizes, the smallest of which deals with steel studs from $\frac{1}{8}$ in. to $\frac{1}{2}$ in. or brass up to $\frac{3}{8}$ in., while the largest has a range in steel from $\frac{1}{4}$ in. to $\frac{7}{8}$ in. Welding supply is drawn from engine generators or transformers, the requirements being 300 amps. (level or drooping) for $\frac{1}{2}$ in. studs, and 600 amps. for $\frac{3}{4}$ in. studs. In addition, a mains supply (230v AC) is required to operate, through a transformer/rectifier supplied, the control circuits, including the timing controller. For the larger sets, this latter equipment is housed in a small trolley-cabinet of similar dimensions to a single operator welding transformer. The actual welding tool weighs about 5 lb. and is fitted with adjustable legs to ensure correct positioning. Actual time of welding averages ·4 seconds, and it is claimed that six small studs, or three larger ones can be welded per minute by an accustomed operator. The finished weld includes a small fillet round the base, which can be removed without seriously weakening the weld, or can be allowed for by counter sinking the nut, or plate, fitting over the stud, or by special preparation of the stud point.

16. Studs are made by the firm to a particular specification, whether steel or brass, and are specially shaped with a conical tip. They can be produced up to any length, while adapted collets can be provided for welding split pins, lugs and other attachments. Welding is satisfactory on any thickness from twenty-guage sheeting up to armour plate.

17. While this machine is unlikely to have field application, it might be of great use in base workshops, transportation or in mass production of fabricated steel articles or structures.

## Light Alloy Welding

18. Light alloys may be welded with metallic arc electrodes (including the Argon-arc and Heli-arc processes), oxy-acetylene gas, carbon arc electrodes and atomic hydrogen. In metal arc welding the technique differs from steel welding, but can readily be learned by skilled welders. Equipment required for metal arc welding is a D.C. generator set giving up to 400 amps. with constant voltage, a holder suitable for high amperage, and a welder's respirator (only if welding in confined spaces).

19. Electrodes generally in use are the five per cent silicon type, though others are being developed. The coatings are hygroscopic, so the electrodes must be kept dry at all times. They can be baked in an oven just before use to ensure that no moisture is left in the coating. The thermal conductivity of the alloys is so high that a lot of heat must be put in during welding—hence the amperages used are high, e.g., 300 amps. for a $\frac{1}{4}$-in. fillet weld.

20. Practically all the wrought alloys can be welded, but the strength of the joint is not necessarily equal to the strength of the parent metal—in many cases it will be below. Many alloys achieve their strength through heat treatment (quenching, etc.) ; welding softens such alloys and also affects

work-hardened material. Some success has been achieved on the alloys containing little or no copper, such as STA7/AW10, which has about 1 per cent each of Mg., Si. and Mn., and 0·6 per cent of Fe.

21. Only down-hand welding is at present practicable. For butt welds in plates, no edge preparation is required for ¼ in. or below. A backing strip of iron or copper may be necessary to prevent too much penetration. For thicker butt welds, double Vee preparation is used. Fillet welds are done in the 45° position—i.e., with the work positioned to form a natural Vee. Properly designed jigs are required to hold the work and avoid distortion.

22. Pre-heating is not essential, but it is found that an initial heating reduces porosity in the weld. For heavy work, it is recommended that pre-heating to about 150°C. be carried out, and the edges to be joined should be carefully cleaned by scratch brushing.

23. The electrode is connected to the positive terminal, and held perpendicularly to the work, a short arc being maintained. Welding is about three to four times as rapid as in steel, owing to the low melting point of the electrode. The electrode should move along in a straight line with no weaving. Craters may be avoided by the " step-back " method. Tacking, if required, is similar to steel construction.

24. The slag formed after welding is very corrosive, and all traces must be removed by brushing or light chipping. A good weld has a reasonably smooth profile, and is easy to clean ; poor welds will entrap the slag in their edges, and more care is necessary to ensure complete freedom from slag. Washing in hot water will remove most of it, and should always be done.

## Oxygen and Acetylene Gas Generators

25. The supply of filled oxygen and acetylene cylinders has always been a matter of difficulty in the field. A possible alternative is the on-site generation of these gases.

26. Acetylene generators are produced in sizes from 12 cu. ft. to 200 cu. ft. per hour at about 9 p.s.i. A typical set from this range has the following characteristics :—

Weight empty—125 lb. ; charged—400 lb.

Charge of carbide—25 lb. ; of water—25 gallons.

Gas produced per charge is 112 cu. ft. similar to the normal acetylene cylinder weighing 112 lb.

Thus for static purposes, the generator has a weight advantage of 112 lb. minus 25 lb. from a bulk re-supply point of view ; for mobile purposes, the weight of water, and of the charged generator outweighs this advantage.

27. Oxygen generators, on similar lines, have also been produced, but not yet in this country. They suffer from the following disadvantages :—

Chemical used (Sodium Peroxide) is unstable, and dangerous to handle ; it needs special containers, and generates great heat on contact with water.

A maximum pressure, without auxiliary compressors, of 30 p.s.i. only is possible.

Effluent is strongly caustic.

Other oxygen generation methods include special candles, from which generation is at a slow rate and low pressure.

28. Summing up, oxygen on site generation does not yet appear to be practicable ; acetylene on site generation should be considered for static installations. The apparent advantages of weight in re-supply of both systems might well be negatived by a reduction in weight of existing cylinders, now under investigation.

# THE SITTANG RAIL FERRY

*By* Colonel S. K. Gilbert and Captain G. Holliday (Late R.E.)

THREE miles east of the river Sittang, in the district of Kyaikto, lie the Mokpalin quarries, where before the war 1,500 people were employed by the Government extracting laterite and granite which was sent to all parts of the country. The output was, by a considerable margin, the largest in Burma. The principal method of distribution was by rail and the quarries were linked to the main line of the Burma Railways system from Martaban to Pegu at a point just south of Mokpalin station. Quite a quantity of stone was also transported by country craft over a network of channels and canals of the Sittang, Pegu and Rangoon rivers. To facilitate the loading of these craft a single line ran down to a jetty on the river bank about a mile south of the railway bridge across the Sittang. (See Plate 1 at end of this article.)

The war with Japan started and a fighting retreat from Southern Burma by troops of 17 Indian Div. passed through Mokpalin. The railway bridge over the river, which is over six hundred yards wide at this point was, destroyed during a disastrous battle when all the divisions' guns and nearly all its vehicles were lost. (See Photo 1.) During the Japanese occupation the quarries remained idle and they were very rapidly swallowed up by the dense scrub. The Japanese had no interest in them, their main concern being to maintain their L. of C. across the river Sittang. A rail crossing north of the bridge was begun, diversion lines were laid and timber piles driven out from each bank, but the job was never completed before their capitulation.

It was very quickly realized that it was essential to reopen the quarries as rapidly as possible and get them working, as roads in particular were in an appalling condition and needed major repairs, necessitated by heavy military traffic and lack of maintenance over a period of four years. In fact, their condition had sunk far lower than those in the European or African theatres of operations. The problem of how to get rolling stock across the river Sittang, which had faced the Japanese Engineers, now had to be tackled by the 12th Army.

At a conference on the 21st September, 1945, called to discuss the method to be adopted in order to provide the delta area with 1,000 tons of stone per day, various schemes for getting the stone across were examined, i.e., by using an aerial ropeway over the existing bridge alignment.; by fitting R.C.Ls. with rails and adapting the old jetty ; by loaded lorries and dumping the stone into wagons at a convenient point on the west bank, etc. As a result of this conference it was evident that a good-sized scheme was necessary to provide the stone asked for, and it was decided that the bulk of the work at the actual river crossing should be done by the Port Construction and I.W.T. operating branches of Transportation Directorate, Burma, with specialized assistance from the Railways branch. The C.E. 12th Army undertook the rebuilding and strengthening to 10 B.S. loading of bridges and culverts on the approach line from Pegu, which included a Bailey lift bridge over the canal at Waw, and he also provided engineer troops for works at the river terminals.

On 2nd October, a survey party from the D.D.Tn., Port Construction, left for Sittang to survey levels in the terminal areas, obtain soundings, details of existing structures and the river bed, tidal curve readings and observe the set and strength of the currents and the behaviour of the bore. The latter was of paramount importance because the river had a bad reputation.

The river rises in the Shan hills of the Yamethin and flows some 350 miles south to the gulf of Martaban. It was never of any value for navigation, except to small country craft, owing to two factors ; firstly the river is very unstable, it tends to get wider and shallower and the main channel keeps shifting its course by continuous erosion and deposition of sandbanks ; secondly, the river is subject to a tidal bore which occurs at certain phases of the moon when two currents in its estuary unite to form a tidal wave. The wave is followed by a great turbulence and rushes up the river at twelve to fifteen m.p.h. making a noise which can be heard up to two miles away.

No information as to river levels, tide, or any other subject was available, although such information must have been recorded before and during the construction of the bridge. From early estimates the tide appeared to vary from about 6 ft. at neaps to 16 ft. at springs. The river was seen in October at maximum flood level, but the amount of drop in the dry weather was unknown. Accounts of the bore were very varied, but it had earned considerable notoriety by wrecking some 75-ft. motor minesweepers of about 120 tons. Eye witnesses gave estimates of a wave up to 12 ft. high on this occasion. It was clear that accurate data had to be tabulated before any detailed design or construction could proceed.

However, with the survey in hand and following a recce by Field, Port Construction and Railway Construction officers, preliminary visions crossed the designer's mind and lists of stores were drawn up. As with most work tackled in this theatre it was necessary to ascertain what resources were available. An intensive search of the Tn. stores depots, Port Commissioner's Yard, the Naval Authorities' Yard, the Boom Defence Officer's Stores and the Port Area in general was vigorously pursued and details noted. No craft were available for use as ferries or landing stages, nor was it possible to tow any up from Rangoon. It was therefore decided to use P.C. (Port Construction) pontoons for both purposes. P.C. pontoon is built from plates and special corner sections into units 13 ft. 6 in. long, 5 ft. 5 in. wide and 5 ft. 6 in. deep. It is similar to a sectional water tank turned inside out. Specially shaped half-length units are supplied to give a " scow " end to assemblies which have to meet or pass through the water. Some 1,800 units had already been fabricated for Port work in Rangoon, so ample experience had been gained, and their scope and limitations were fully understood.

On 4th October, fabrication of P.C. pontoon units was commenced on slipways in Rangoon leaving the size and shape of the final assemblies for determination later. They were then assembled into " rakes " suitable for towing up the Pegu river, along the Waw-Sittang canal, through the lock at Myitkyo and so down the river Sittang to the site, a distance of some 150 miles.

A few days later Bailey bridge components were collected and transported to the Port Commissioner's Yard, where the stores were being assembled. The first detachment of the Port Construction Company arrived at the site on 11th October, established a camp and made preparations to receive the first lift of equipment and material. There was a tremendous rush to get the first tow ready, because it was only possible to pass through the Waw-Sittang canal on spring tides and even then there was only 4 ft. of water.

On 20th October, the tow left Rangoon hauled by " D " type tugs. The

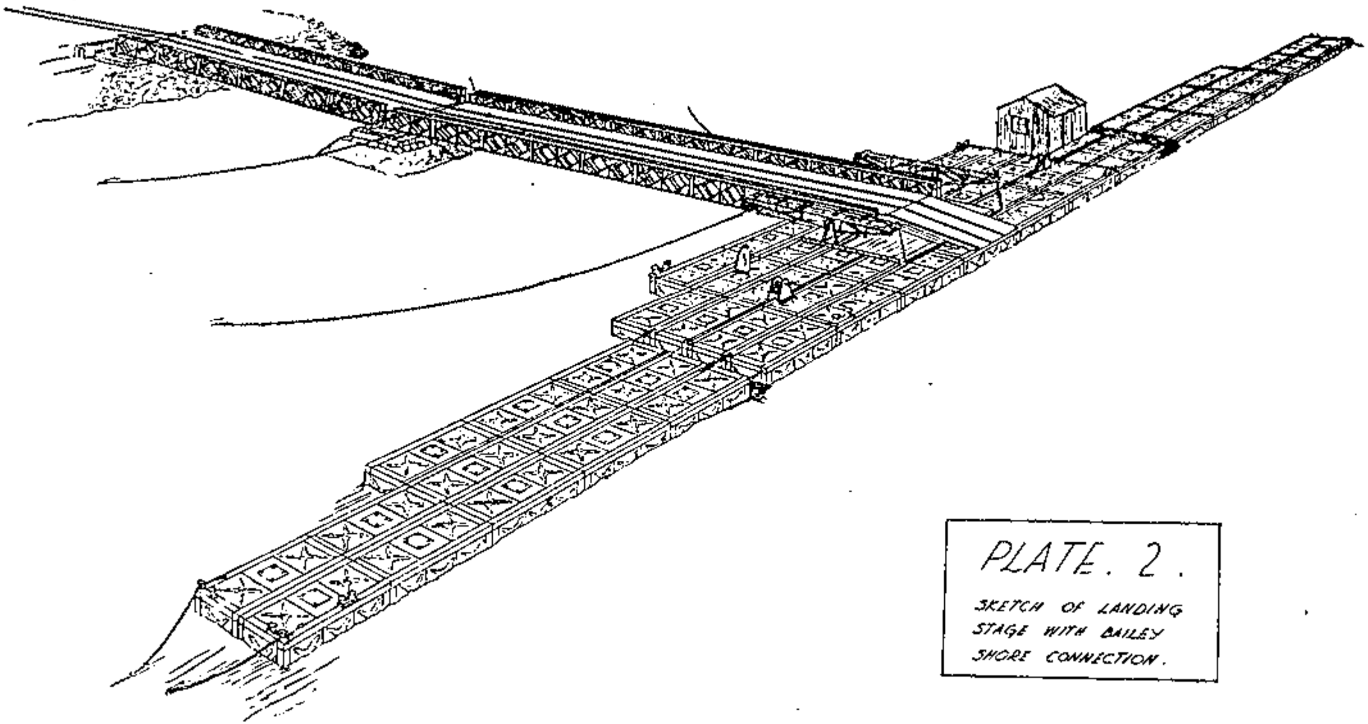


PLATE. 2.

SKETCH OF LANDING STAGE WITH BAILEY SHORE CONNECTION.

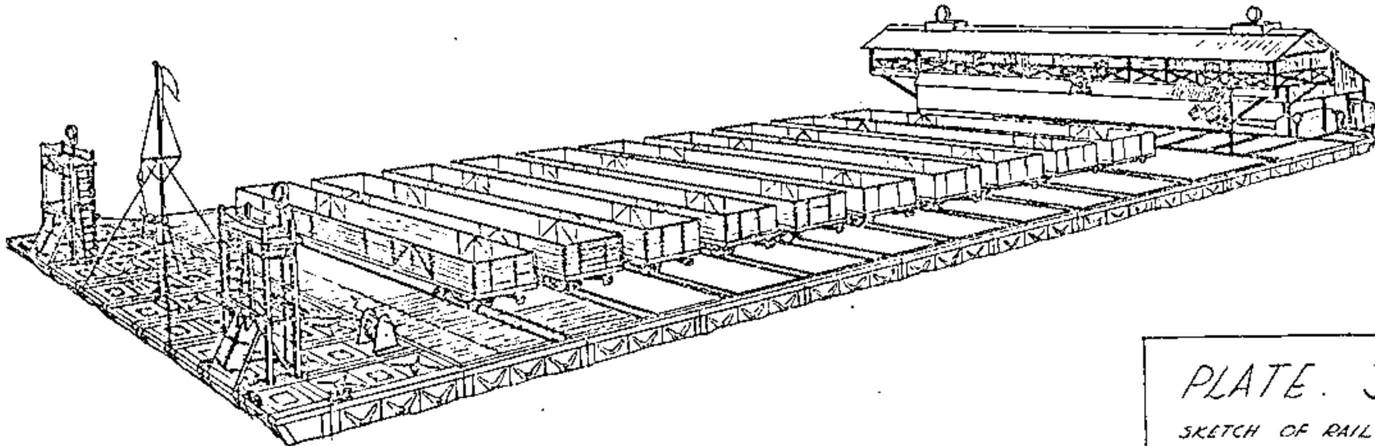


PLATE. 3.

SKETCH OF RAIL FERRY CARRYING TEN AMERICAN BOGIE WAGGONS pontoons were stacked high with pile driving equipment, welding sets, cutting sets, Bailey Bridge components, hundreds of small tools and miscellaneous timber, including piles. The tents for the passage crews were pitched on the pontoons among this conglomeration of engineering stores.

By this time, design had progressed, detailed drawings had been prepared and with the generous assistance of a Survey Reproduction Unit, numerous copies turned out for use in Rangoon and on the site. The requirement of 1,000 tons of stone a day would fill either forty bogie wagons or eighty four-wheeled trucks. It was evident that owing to the tidal conditions there would be some days in each fortnightly high tide cycle when the ferry could not work and many days during which it could only work very limited hours. Provided each ferry averaged two trips per day the required load would be dealt with. It was therefore essential to have reliable craft. The eventual decision was to provide two ferry craft, each capable of carrying seven bogie wagons or fourteen four-wheeled trucks. These were later to be increased in size to carry ten bogie wagons or twenty trucks, as and when more P.C. pontoon units became available. Propulsion was to be by three 110 h.p. Murray Tregurtha outboard motors, since tugs could not be retained to operate the ferries.

Design of the landing stages presented a much greater difficulty. They had to rise and fall with the tide, which had a maximum variation of 14 ft., and to this must be added the annual change in level of the river in the region of 10 ft. They had to withstand the 8-ft. bore. All landing stages move up or downstream a little when the direction of the current under them changes. As the maximum current here reaches ten knots (following the bore) the movement would be considerable. This had to be allowed to take place without deforming the railway, that is without changing the centre line of the bridge.

Efforts were made to plan an end-loading landing stage—like those of the ship-type train ferries in Europe, where the business of registering the shore tracks with the ship tracks has only to be done once for a loading. With this type of ferry fixed fenders piles may be arranged to assist the exact positioning of the ship. As no scheme could be devised which did not either involve heavy constructional work for the landing stages if the ferry were to berth parallel with the current, or the very difficult operation of berthing across the current if it were not, this arrangement was abandoned, and the less efficient, but more usual design of ferries across a river, in which a number of short tracks are laid across the craft, instead of a few along it, was adopted. This arrangement has the great disadvantage that for a single-track landing stage, each track on the ferry has to be brought opposite the landing-stage track in turn making the loading of this type of ferry comparatively slow. (See Plate 2 and Photo 2.)

The length of the landing stage was governed by ease of working the ferry—its face should be equal to the length of the ferry plus the length of travel when the ferry was alongside the stage and each track being loaded in turn. This length of over 200 ft. would have produced excessive "hogging" and "sagging" moments when the short steep waves of the bore passed underneath. Also a rectangular pontoon of this length would have required a large number of units. It was therefore decided to split the landing stage into three separate sections. The centre section had sufficient units to support the bridge load. The end sections were mere working platforms and were tapered off accordingly (see Plate 2). This taper, of course, diminished the blow of the bore on the stage by taking it up gradually as the wave met each successive projection. The upstream dead sections protected the centre section with its load and their attachment, and by damping the pitching moment to which it was subjected they prevented the end of the centre section being " tossed into the air."

Tidal variation was allowed for by the usual half-floating span, in this case an 80-ft. triple single Bailey. The shore ends of these spans were seated on intermediate piers, in the case of the east bank supported on a bagged concrete foundation placed on a rock bottom, and in the west on piles of a jetty built by the Japanese. Similar Bailey spans connected the intermediate piers to the true bank seat, three to the east and one to the west respectively.

Advantage was taken of this arrangement to diminish the maximum rail gradients by arranging for the intermediate bridge seats to be jacked up during the flood season and let down during the dry weather. The gradient could not, however, be reduced to less than one in ten at the lowest tides. It was therefore arranged that rolling stock should be moved up and down these gradients by caterpillar tractors (D.8s). The approach spans and ferries were flush-decked with timber level with the rails, so that the tractors, or any other vehicles, could move freely. A special heavy tow bar was fixed by a swinging joint to the tractor, and this gripped the centre coupling on the rolling stock.

Having arrived at the landing stage end of the Bailey bridge, further minor variations in level had to be provided for. As the load moves on to it, the landing stage sinks about nine inches. Similarly the exact height above water of the tracks on the ferry varies two feet between full load and empty. The ferry also tilts a little as the load rolls on and off. The final adjustment is effected by an 18-ft. ramp hinged to the end of the Bailey bridge with its free end hooked over a rail on the gunwale of the ferry. This ramp was counter-balanced and lifted by a winch.

A first design to provide for all the " degrees of freedom " in the seating of the bridge on the landing stage produced a trough in which a large diameter hemispherical seating would rock and slide. The necessity, however, of keeping the constructional depth of this fitting very low made the manufacture excessively complicated and it was abandoned. Instead the bridge was placed on normal Bailey seatings, which were themselves free to slide on a flat plate as change of current moved the landing stage slightly upstream or downstream of its true position. The rocking motion produced by the bore was allowed to rock the half-floating span, which itself sat on a hemispherical seating on the intermediate pier, leaving it free to rock at the shore end where greater constructional depth was available. Provision was made for inserting wedges under the Bailey girders when traffic was passing. The wedges, of course, had to be removed before the bore was due.

Heavy connecting links between the shore span and the half-floating span were placed as near as possible to rail level, to keep the rail length constant irrespective of the vertical movement of the landing stage. The ball seating was therefore free to slide over the plate.

Given the conditions of ten athwartships tracks, the dimensions of the ferry craft sorted themselves out as 165 ft by 50 ft. They were sizeable craft, with a displacement tonnage of about 600 (see Plate 3 and Photo 3). The Murray Tregurtha outboard engine is arranged to steer by turning the whole propeller assembly round its vertical axis. For a craft which has to spend a large part of its time " coming alongside " the ability to exert an athwartships thrust with the propellers is very valuable. It was therefore decided to retain this method of steering instead of leaving the propellers fixed and fitting rudders.

The Murray Tregurtha steering gear is operated by a small wheel placed

Photo 1.—Sittang Bridge 1945.

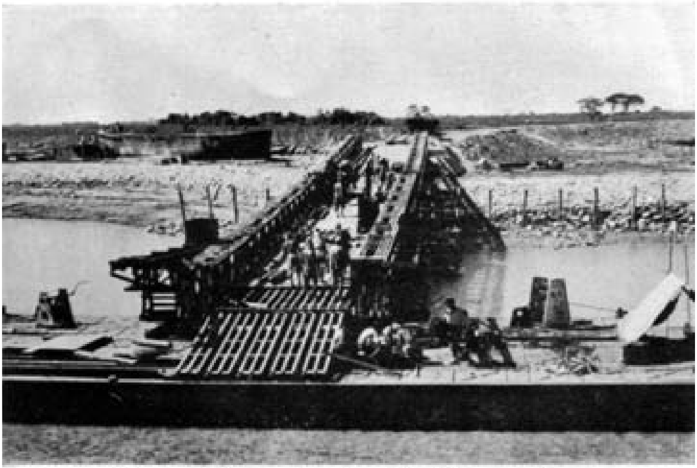


Photo 2.—The West Bank Terminal under construction.

# Sittang Rail Ferry

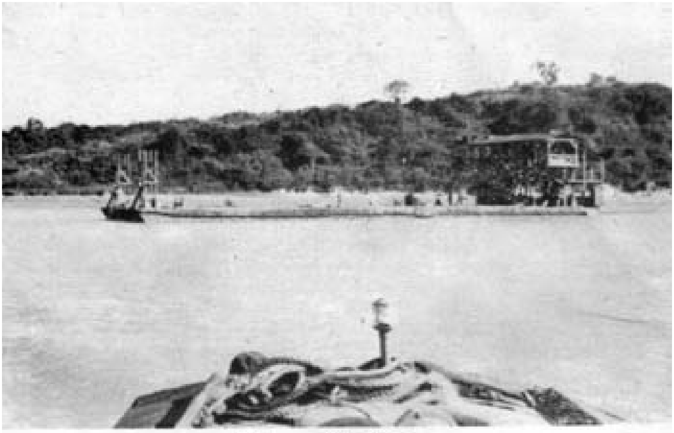


Photo 3.—R.F. *Patience.*

Photo 4.—The bridge and stern of a ferry.

# Sittang Rail Ferry 3-4

so that it can be turned by a man standing next to the engine. In this position a steersman would have his vision obscured by rolling stock on the pontoon. A navigating bridge was therefore built across the ferry, 15 ft. above deck level, to give a good view and extending to the sides of the vessel so that the captain could look straight over the side when docking. A 5 ft. diameter steering wheel was fixed in the middle of the bridge and connected to the steering gear of the centre engine by using condemned jeep driving shafts and pinions. As the force required to steer one engine is considerable, this wheel had to be manned by two men.

Control of the engines for ahead, astern, stopping and starting etc. is normally by throttle, clutch and reversing lever and switches on the engine casing. It was decided that each engine would require its own attendant in any case, so the controls were left on the individual engines, and an " engine-room telegraph " fitted to transmit orders from the bridge. There were three control telegraph pedestals on the bridge, one amidships and one on each beam for docking. Each pedestal had three levers for transmitting signals to the three engines. Each lever had a pointer alongside it operated from the engine control position. Movement of the pointer followed movement of the lever as an acknowledgment from the engine attendant that he had carried out the manœuvre ordered. At the engine control position there was an inscribed quadrant over which a pointer moved Below this quadrant was the lever which, when moved into the same position as the pointer, transmitted the acknowledgment back to the bridge.

In the silt-charged water of the Burmese rivers there had been constant trouble with the glands of the circulating water pumps of the Murray Tregurtha engines. A secondary clear water circulating system was therefore arranged for the engines, the engine cooling water being drawn from and returned to one of the P.C. Pontoon units and itself cooled by loss of heat through the plates of the unit to the river water.

Deck fittings included the usual bollards and fairleads. Each ferry carried two 40-cwt. anchors on inclined platforms at the bows. The anchors could not be carried overside as their size would cause them to foul the bottom when the ferry was moving in shallow water. The platform enabled them to be carried above deck without the complication of anchor davits, moreover they could be dropped instantaneously in an emergency (see Plate 3). The method of raising was by hand winches using a 3-in. steel wire rope as cable made fast by screwing up three bulldog clips through which it passed, these clips taking the place of the chain cable grips on a normal vessel.

For operation at night the ferries carried four Tilley Flood Lamps. Two of these were on platforms above the bridge roof and two on towers above the anchor platforms forward. The latter faced forward for navigation and could be turned like searchlights by a lever at deck level. When loading and unloading rolling stock they were turned right round to assist the aft pair in illuminating the deck. The usual navigation lights were carried on the mast and ends of the bridge.

It need hardly be added that these craft flew the R.E. flag.

As two watches were carried, the ferry crew totalled four officers and twenty-four O.Rs., at first I.W.T. but later all locally recruited civilians. The officers were accommodated in double berth cabins opening off the bridge. The crew were berthed in bunks in a half deck over the engines. Under the bridge were the galley, mens' mess room, washing place and store. There was a bench with fitters' vice for the engine mechanic. Sanitation was on the " direct system " usually employed on small craft in these waters. In planning the accommodation, airiness was the principal consideration, combined with wide "eaves" (a somewhat unmaritime term) to give shade in the dry weather and shelter in the monsoon (see Photo 4). Chittaya matting was used for all partitioning and was made up and fixed by a local Burmese villager.

As the ferry had to be moved into ten successive positions alongside the landing stage, and held exactly in each one in turn, special arrangements had to be made for "making fast." On coming alongside the stage, manilla ropes were cast aboard at bow and stern. These were hauled inboard, bringing snatch-blocks on their ends through which a 3-in. S.W.R. ran, the snatch-blocks were then hauled up to the bitts and made fast. Each length of S.W.R. was attached to the landing stage at two points so that the ferry could move transversely alongside the stage, the S.W.R. passing through the snatch-block as it does so, but was all the time held fast alongside. One end of each of these loops of wire was taken to a winch. This winch could, of course, be used in the first place to draw the ferry tightly alongside. A single turn of the handle would then slacken the wire enough to allow the ferry to be traversed. When the projections on the end of the 18 ft. ramp had dropped into slots on the ferry's gunwale, that is when the ferry and landing stage tracks were registered, another single turn was sufficient to lock it in position.

Traversing of the ferry was done by another winch. As soon as the ferry was made fast, a length of 2-in. S.W.R. with a loop spliced was passed over a bollard at the stern, the other end being passed aboard at the bow and made fast to a tensioning tackle which was then pulled tight. This 2-in. S.W.R. passed along the landing stage and was taken on to and off the drum of the traversing winch, and so by winding on the traversing winch the ferry moved along the landing stage. If a strong current was running the ferry would run its engines to provide the extra necessary power. The traversing winch then merely supplied the exact and minutely adjustable control required to cause the tracks to register.

For towing to the Sittang, the pontoon units were joined into assemblies not exceeding 17 ft. wide. The first convoy took longer than was expected owing to heavy currents, and the day when the D.D.Tn. flew over the route he found them spread out and making very slow progress. It had originally been intended to tow up the sections with the Murray Tregurtha power units on board, as the heavy timber keels which protected the propellers could not be fitted before towing and the propellers might have suffered damage in shallow parts of the channel. However, needs must, and a party was organized from the Port Repair Ship R.E., the *Swift*, to move the flotilla to the Sittang. With a "J" launch ahead to check the depth of the water the flotilla consisted of six sections of pontoon 48 ft. by 17 ft., each propelled by its own outboard engine, four "D" tugs towing other pontoons, a spare "D" tug, the *Skylark*, and a motor dinghy. After much hard work, break-downs, groundings, etc., the flotilla reached the Sittang in eleven days.

As pontoons were fabricated and launched, further "tows" were assembled and dispatched to Sittang, on 29th October, 3rd and 12th November, respectively. In addition to the stores sent on the pontoons, a fair quantity were loaded into special trains which conveyed them from the Port area in Rangoon to the west bank terminal of the ferry at Sittang. Work was carried out on both banks simultaneously using "J" launches and a "D" tug, and of course the *Skylark*, and later the ferries themselves, for communication, movement of personnel and stores. The west bank terminal had much work for the Field Engineers, including forming the 350 yds. of embankment from the existing main line, bridging a small Chaung using piled foundations, and the strengthening of the old timber jetty to take the "inshore" span, As this proceeded the Railway Construction detachment laid the track. On the east bank the Field Engineers built a stone abutment wall and extended it inshore to prevent erosion by the river, and the piers for the bridge spans. While this work was proceeding at the river crossing a company of the Madras Sappers and Miners with some two thousand J.S.Ps. (Japanese Surrendered Personnel) had cleared away the accumulated dense overgrowth in the quarry, dug out the railway tracks, restored the old roads and bridges, built new approaches and installed drilling and crushing equipment. Immediately they were in a position to dispatch stone, tipper lorries were used to carry it to the nearest suitable railhead which was at that time at Waw. This involved driving from the quarry at Mokpalin to the R.C.L. crossing at Sittang, over the river, then a nineteen mile drive over an appalling dry weather road which for the most part had a top surface of one foot of fine dust. On reaching Waw they tipped the stone into railway trucks which duly conveyed it to the Rangoon area.

On 16th November, after a period of observation, it was found that the river was falling very considerably and it was not clear how much lower it would drop. It was possible, and actually done, to walk right across the river at neap tides. Naturally it was the terminals which were most affected by this drop in level. On the west bank a sandbank, 300 yards wide, was deposited immediately in front of the ferry terminal and parallel with the river bank, forming a bar right across the projected ferry route. At the east terminal on the other hand many pinnacles of rock were revealed. Some had been located in the original survey, but they now proved more numerous and constituted a serious danger to the pontoon equipment.

The dispersal of the sandbank was tackled by lashing the two partially completed ferries together and then with their outboard engines running at about 2,000 r.p.m. and propellors set nearly horizontally just above the sand they moved forward at three or four feet a minute and thus caused a turbulence sufficient to stir up the sand which was in turn cleared away by the scouring action of the tide.

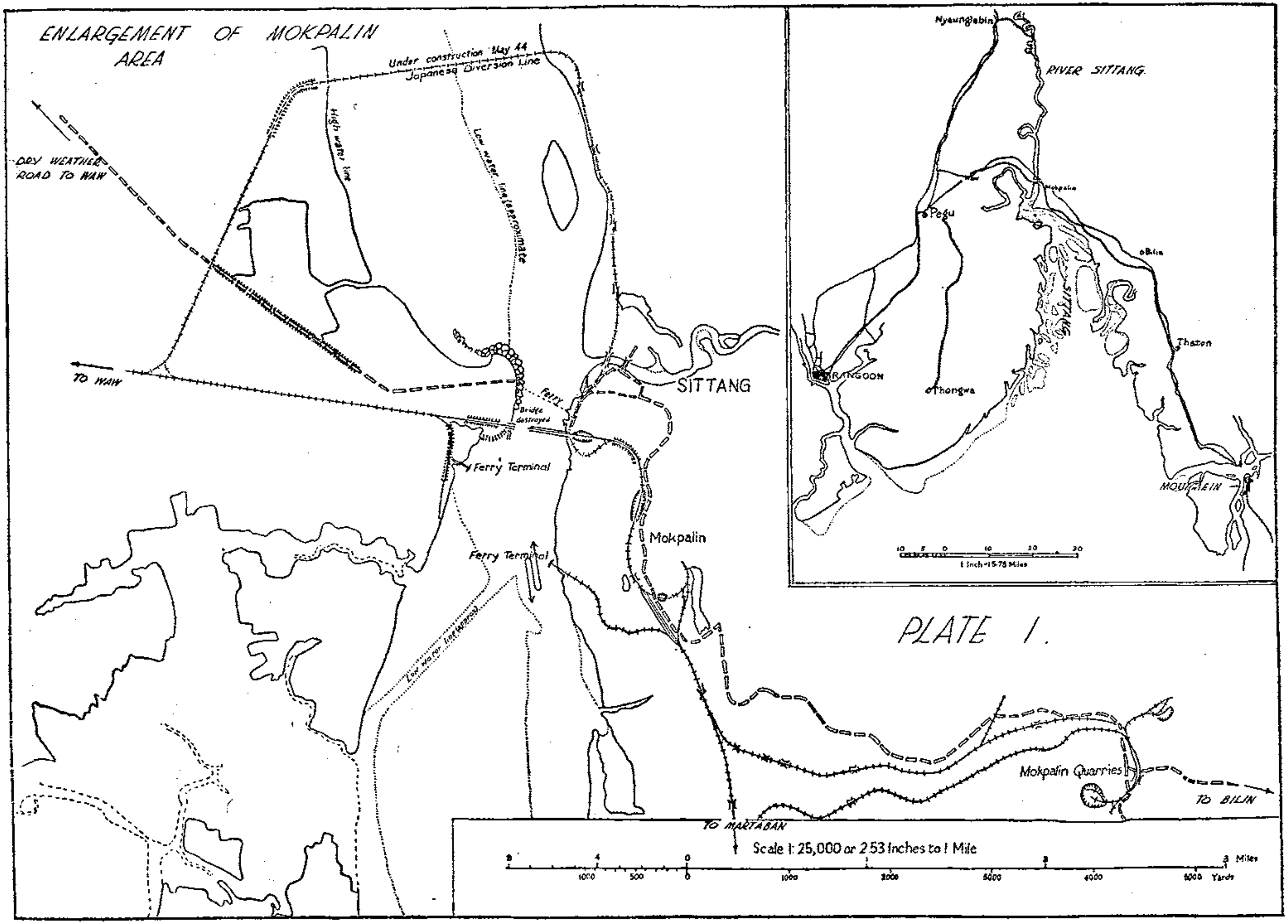
The pinnacles of rock provided a very different problem and blasting with high explosive appeared to be the solution. Miscellaneous Japanese explosives and R.A.F. U.X.Bs. found lying in the vicinity of the bridge were placed round the larger pinnacles by a diver and fired. This did not, however, prove effective, although most spectacular. It was finally decided to extend the bridge 180 ft. further out into the river and so ensure plenty of water under the floating end of the terminal.

The decision was made when the river was on neap tides so it was essential to press on with the construction of the piers while the water was low. A hundred J.S.Ps. carried the 350 tons of dry concrete in bags from the river bank, across a flimsy bridge made of planks supported by small craft, pontoons and anything buoyant, to the sites of the new piers. The initial placing was done by divers. This work went on day and night at a speed which reflected credit on all concerned and resulted in the piers being just completed before the high tides set in. The fabrication of the extra spans was quickly carried out and those between the piers were launched from the shore while the half-floating span was made up on one of the ferries and then placed in position between the last pier and pontoon. Track-laying across the new spans followed and with the final moorings in position the bulk of the work on the east bank had been completed.

On 15th December, work had progressed sufficiently on the ferry terminals and the ferries themselves to allow a loading test to be carried out. A ferry was brought to the west bank terminal, moored and lined up for the test.

It would not be untrue to say that both the bridging equipment and the ferries, and by no means least the bulldozer driver, "had their moments." A great deal was learnt from the test, particularly the necessity for the floating landing stage to be as low in the water as possible so as to lessen the steepness of the ramp which forms the link between the bridge and the ferry. Another snag which appeared was that the type of coupling used on Burma Railways had no vertical play and so the couplings locked when one wagon was on the ramp and the next one horizontal on the ferry. A further test was carried out on 19th December, when a locomotive was taken for a trip with more success, resulting in only a few very minor modifications. The D.Tn. now christened the ferries *Pinafore* and *Patience* and the only work then outstanding was the completion of the superstructures on the ferries and this went ahead rapidly as personnel became available from work on the terminals. At the beginning of February, 1946, tidal observations, which had been most meticulously kept and latterly entrusted to J.S.Ps., showed that the bore wave was becoming much larger, as high as 6 ft., with correspondingly intense turbulence following its passage. *Skylark* accordingly laid further moorings to the bridge pontoon to ensure its safety. With this done the construction work came to an end, and on the 10th February, the last of the construction troops were withdrawn leaving a skeleton maintenance party for instructing those who were to operate the scheme and also to effect modifications and repairs if necessary. The design of this work was a fascinating task in which entirely new problems presented themselves by dozens. Our ability to build half-floating spans for railway loads out of standard equipment and in one of the most difficult estuarial sites imaginable opens up visions of rapidly constructed floating railway bridges. The construction, at a comparatively inaccessible spot, of train ferries of 600 tons displacement and a speed of seven knots, again from standard equipment, is no less pregnant with possibilities.

The execution was a pure joy in which each unit pulled the harder the more difficulties it found in its way. Co-operation was excellent. The Port Repair Ship, with its "landing party"—going away up-country in craft of their own construction had the most fun, something like a "Marryatt" story. The units taking part were:—C.A.G.E. 471, with C.R.Es. 111, 457 and 4 Corps troops, 75 Field Coy., 6 Engineer Bn., 711 and 749 Mechanical Equipment Platoons, 168 Indian Rly. Construction Coy., 229 Port Construction Coy. and 979 Port Repair Ship.



ENLARGEMENT OF MOKPALIN AREA
Under construction May 44
Japanese Diversion Line
High water line
Low water line approximate
DRY WEATHER ROAD TO WAW
TO WAW
Ferry
Bridge destroyed
Ferry Terminal
Ferry Terminal
SITTANG
Mokpalin
Low water line approx
TO MARTABAN
Mokpalin Quarries
TO BILIN
Scale 1: 25,000 or 2.53 Inches to 1 Mile
Miles
Yards
Nyaungkebin
RIVER SITTANG
Mokpalin
Pegu
Bilin
SITTANG
Thaton
RANGOON
Thongwa
MOULMEIN
1 Inch = 15.78 Miles
PLATE I.

# "CLOVER"

*By* LIEUT.-COL. D. W. R. WALKER, M.B.E., R.E.

"CLOVER" was to have been a floating airfield, easily transportable and quickly assembled, suitable for the operation of Naval aircraft up to the weight of a fighter bomber of the Fleet Air Arm. She was to be capable of lasting for at least a month in sea conditions normally encountered in enclosed waters. This meant that she had to be strong enough to stand up to waves 4 ft. high and of wave length not less than 80 ft.

This projected floating airfield was a development of the Mat Bridge of which a brief history is given below.

## THE MAT BRIDGE

In about 1928, Major G. le Q. Martel, R.E. designed a novel type of floating bridge. It consisted of a string of planks, laid close together and joined by flexible steel strips, which was stretched across a water obstacle. The buoyancy of the planks alone was not enough to support any appreciable load, but if a vehicle drove across at a certain minimum speed, it was supported by the inertia of the mass of water which it pushed along in front of it. In fact it rode its own bow wave. Although the experiment was successful, there is no record of its having been taken up for practical purposes. The objection presumably was that if a vehicle stalled in mid-stream, it would destroy the bridge besides "writing itself off" in the river.

### *The Indian Mat Bridge*

Amongst other subsequent experiments which introduced the use of waterproof canvas with modifications of the Martel Mat, was one carried out by the 4 Fd. Coy. of the Bengal Sappers and Miners at Roorkee in September, 1939.

A large tarpaulin was covered with a bamboo trellis in which the bamboo was spaced about 9 in. apart. The edges of the canvas were turned up over a straw filling and stitched down so as to make a padded float all around the "mat." Inverted steel channels were placed on this, correctly spaced, and with its wheels on the channels, an empty 30-cwt. lorry was gingerly driven on. The experiment is recorded in Photo No. 1. Although the resulting flotation of the lorry was quite normal, it surprised those who were watching. The depression caused in the "mat" was hardly noticeable, and the enormous load which a waterproof textile material, spread on water and suitably reinforced, can carry became apparent.

After this, all available old tarpaulins were "scrounged," patched and sewn together to form a sheet about 100 ft. long and 12 ft. wide. This sheet was provided as before with buoyant edges, and bamboos were placed at 9-in. intervals along it in order to give it sufficient cross stiffening. A very simple decked roadway consisting of 2½-in. chesses lying between light section angle iron runners, completed the bridge. (Photo No. 2 shows a lorry crossing it.)

About a year later, the great shortage of all types of bridging equipment in India became a serious problem for A.H.Q. Orders were therefore given for an experimental "mat" bridge, capable of taking class 5 loads, to be made in Lahore.

Now there were many fundamentally weak points in the first Indian Mat Bridge which has been described above. The worst of these, which are mentioned below, had to be eliminated somehow, or there was no hope of ever making it into a military equipment bridge.

The main weaknesses were :—

(*a*) If the straw stuffed edges of the " mat " became waterlogged at any point the whole bridge was liable to be swamped.

(*b*) The bulk and weight of a canvas sheet, of sufficient length to cross a gap of 200 ft., would be so great that it would be impossible to handle.

(*c*) The bridge was much too weak in its length. More and bigger steel members would have to be provided.

The first of these difficulties was overcome by specifying a (relatively) permanently buoyant material, such as Kapok for the stuffing of the edge, and by enclosing it in watertight bags which were separate from the " mat." Thus, even if the water accumulated at the edges of the bridge, the dry stuffing in the bags still held the edges of the " mat " above water.

(*d*) Weakness presented a more difficult problem. The longitudinal members had to support the chesses but could not project downwards. If they did, they would damage the " mat." Eventually the chesses were laid on steel flats which were suspended from small section steel joists by means of iron stirrups. The joist above the decking and the flat below gripped the chesses tightly between them. A third composite roadbearer of this type was placed at the centre of the roadway, and enabled a lighter chess to be used than would otherwise have been possible. This construction can be clearly seen in Photo No. 3.

The most troublesome of all was problem (*b*). The canvas used for the " mat " had to be divided into sections suitable for packing and handling, and a simple method of jointing the sections, which would not let the water through, had to be devised. Stitching the sheets together every time the bridge was erected would obviously take too long, and metal clamps were unreliable and bad for the canvas. The solution of the water-tight laced joint, was found when hope of finding the answer had almost been abandoned.

Finally the bridge was demonstrated to officers of A.H.Q. early in 1941, on the Jumna river at Delhi. In words extracted from the official comment on it, which ordered further development :—

" A simple form of bridge, easily erected and based on materials that might be available in any country, has been evolved. No undue complications in design are desirable that would make difficulties in provision or in training other arms in its use."

Subsequently development continued at Roorkee, and after some modifications had been made, it went into production. There were setbacks, one of which was the rotting of a very large number of the tarpaulins while in store in a factory. By the time the equipment reached the field, other better known and more robust bridges were there in plenty. As far as the writer knows the Indian Mat Bridge was never used operationally.

In the meantime work had been started on a mat bridge at home, and a design which had much in common with Mr. R. M. Hamilton's Swiss Roll, was evolved. " Self Floatability " was given a high place in the British Mat Bridge, and steel members were eliminated and replaced by timber ones. The result was a very great increase in bulk and weight over the earlier Indian models. This bridge went to France on " D " day, but nothing is known about its use in operations.

Photo 1.

Photo 2.

Early experiments with the Indian Mat Bridge.

**Photo 3.**—Construction of the Indian Mat Bridge.

**Clover 1-3**

Photo 4.—" Clover " Mk. I. Static load test.

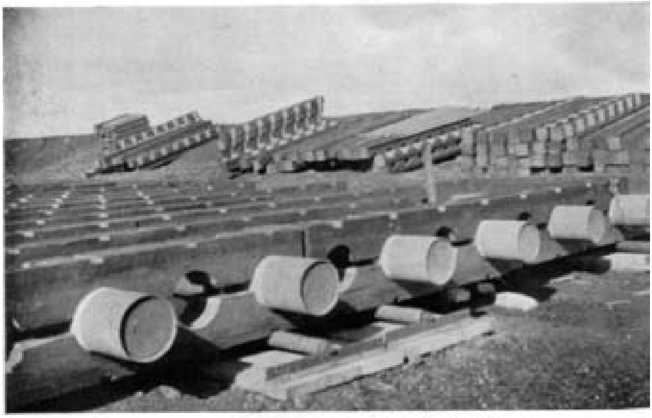


Photo 5.—Construction of " Clover " Mk. III.

**Clover 4-5**

## THE AIRSTRIP

*The Requirement*

The first suggestion for a floating airstrip using the Mat Bridge principle came from G.H.Q. (India) in July, 1943. The requirement then stated was for a landing strip, about a thousand feet long, which could be rapidly assembled and floated, and on which normal close support fighter planes could "land." It was expected to last for about a week in calm water, by which time a shore strip would be ready.

Early in 1944, there was a fairly strong demand for a strip of this kind for the combined operations which were being planned in S.E.A.C. The solution offered by the "mat" type of construction was considered by the Director of Scientific Research at the Admiralty, and he asked for more detailed proposals.

## "CLOVER" MK. I

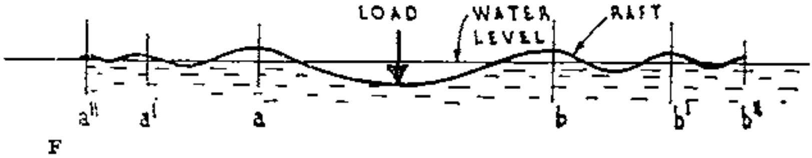
The plans for "Clover" Mk. I were eventually put before a conference of Naval officers at the office of the Director, and it was decided that a small experimental piece should be made up. The Department of Miscellaneous Development of the Admiralty became responsible for production, the Department of Airfield and Carrier Requirements for testing and the Naval Constructors at Bath were given a watching brief over design.

The representative of the last mentioned had one look at the designs and "retired hurt." A lifetime of thinking in terms of inches of steel armour plating, thousands of tons displacement, and many feet of draught and freeboard, took ill to a flimsy raft of canvas, timber and tubes. However he provided the assistance of a professor of the R.N.C., Greenwich, to check calculations or to make them *ab initio* when asked.

*Calculations*

Various calculations were made, one of which, in particular, was enlightening and helpful to design. As can be seen from Photo No. 4, "Clover" Mk. I, consisted essentially of a canvas sheet with a decking of tubes and timber laid upon it. The maximum permissible slope of the deck was specified in the requirement which had been given by D.A.C.R., and for this reason, amongst others, the deflection under load had to be ascertained by calculation before the design could make any progress. The calculation was made by the professor, and the first answers provided by him were obtained by a disarming method of approximating curves to straight lines and segments to triangles. The results of this were so disastrous to design, that recourse to long unopened text books and Cambridge lecture notes became inevitable. After some ammunition had been obtained from them, the sinister figures which had been provided by the expert succumbed to a strong attack.

The problem was then studied afresh. If the conditions were inverted, they could be compared with those of a beam carrying a distributed load with a single support at its centre. Unfortunately the load increased in proportion to the deflection of the beam above its two ends. Viewed the right way up, the support of the water increases in proportion to the depth to which the mat is depressed under load. The total thrust which balances the load is the sum of the diminishing support which the water gives at points farther and farther away from the point of loading. Eventually an example of the very calculation required was found in a text book, and a useful fact established. The shape which the raft takes up is sketched below.



It can be seen that waves form in the structure on either side of the point of greatest deflection. The wave lengths of these waves diminish in proportion to the distance from that point. The distance between the nodes "*a*" and "*b*" is constant for any given modulus of section of the structure. At these nodes, the surface is always above water level. Hence calculation of the deflection under any given load becomes possible. Moreover provided the dimensions of the mat exceed the distance between "*a*" and "*b*," the raft will always form itself into a boat shape when the load is put on it, and the part which carries the load is safe from flooding.

Eventually the design, originally governed to a great extent by experience in practice and "the light of nature," was confirmed by calculations. The Naval Constructors were satisfied.

At this stage the main object of the experiment was to "put the idea across," and to get something made quickly for demonstration purposes. As far as possible parts which were readily available in the market were used. Nevertheless there was great delay in getting some of the components, as all the productive resources of the country were engaged in preparation for "D" day.

*Tests*

Preliminary work was done in the old Mast Pond in Chatham Dockyard. Here the two hundred foot long raft was given static loading tests. After this it was taken to pieces and reassembled in the outer basin of the dockyard. From here it was towed into the Medway and moored in the slack water off the channel. The day was calm and there were no natural waves, so a string of tugs raced round and round and made some substitute ones. These were of very short wave length and amplitude about four feet. "Clover" came through this test successfully. The undulations in her surface never exceeded a height and depth of 6 in. but, more important, the naval officers who were attending the demonstration, some of whom had put on sea boots in anticipation of a wetting, came off with dry feet.

This ended the first phase in the development of "Clover." The damping effect on waves of this large "mat" raft, and its load-bearing capacity had been amply demonstrated.

*Changes in Requirement*

While the work which has been described above was going on, the scope of the requirement for floating airstrips had been increasing. Finally it became quite beyond the capacity of the first trial design. A long period of lying out in rough or even "choppy" water had never been anticipated. It was manifestly apparent that anything which depended on the wearing properties of canvas (even Navy No. 2) for its flotation could not give satisfaction.

The Department of Airfield and Carrier Requirements now asked for something which would remain afloat for a month, without major replacement to canvas, in sea conditions of 4 ft. wave amplitude and 80 ft. wave length. The aircraft which were to use the strip, however, had not, fortunately, grown any bigger.

If these conditions were to be met, the design would have to be radically altered.

## "Clover" Mks. II and III

At this stage a decision was necessary as to whether experiments should continue, and if they did continue, what their scope should be.

There was still a strong demand in the Far East for a floating airstrip, so it was decided that the work should go on. A piece of airstrip long enough for an Auster to land on was to be made, and the minimum length for this was fixed at 500 ft. The width was to be 60 ft. This was to be the next step towards a full size airfield. Funds were provided and work started on a new design.

The following factors governed the proposals for the new design, which was eventually approved :—

(*a*) The structure had to be rigid enough to prevent a landing aircraft from causing slopes in the surface of more than one in twenty.
(*b*) Waves in the surface of the strip, caused by the sea conditions specified in the new requirement, were limited by the same condition as that in (*a*).
(*c*) A completely rigid structure could not hope to withstand the constantly changing stresses caused by an unending succession of waves, so it had to be flexible enough to prevent failure from this cause.
(*d*) The airstrip had to have sufficient spare buoyancy to support the weight of any aircraft which might be parked on it, and to keep the wheels above water level.
(*e*) The deck had always to be dry, apart, of course from the wetting it might get from rain. In other words, on a stormy day the wash of waves breaking over the edge had to be kept off the landing surface.
(*f*) The dismantled strip had to be portable and easily assembled.

It was soon found that if condition (*b*) were fulfilled, then the strip was strong enough to land aircraft many times the weight of the heaviest which had been specified in the requirement. Much was said by doubters about the shock effect and the stresses set up by an aircraft as it touched down. This point was referred to the under-carriage experts who said that it remained partly airborne during most of its landing run. The maximum impact forces occurred just before it came to a standstill.

Floatability was entirely a question of the buoyancy of the individual parts used.

*Construction* (see Photo 5.)

In essence, the construction consisted of light steel tubes, 10 in. in diameter, and closed by the welding of a plate at both ends, which lay end to end across the strip in lines spaced at 1 ft. 6 in. intervals. These tubes were held in place by recessed timber baulks of 9 in. by 9 in. section, above and below them. The baulks were bolted together by rack bolts and gripped the tubes between them. Each baulk was 12 ft. long, and the lines of baulks staggered relatively to each other, and clamped tightly together, formed continuous beams which ran the length of the strip. These beams were spaced 2½ ft. apart in "Clover" Mk. III. The tubes were also staggered at half their length across the strip. The recessing of the timber baulks reduced the effective cross-section of the timber considerably, but was essential to prevent the thin steel tubes from being crushed between them.

In "Clover" Mk. II an anti-splash layer of canvas was placed over the top baulks, but this was dispensed with in Mk. III. The landing surface consisted of timber chesses held in place by steel keep-pieces.

The closed steel tubes were of No. 7 gauge and displaced about half their own volume of water. The baulks were Douglas fir or Oregon pine which weighed about 40 lb. per cubic foot. Permanent buoyancy was a necessary quality of the timber used, this characteristic is by no means universally applicable to timbers which float when first put in water.

Allowing for the weight of the small steel parts used, the buoyancy available to support superimposed loads was about 15 lb. per square foot of surface area. A fully loaded Mosquito would need an area of about 15 yds. by 15 yds. to itself to ensure that it did not depress the deck below water level.

Factor (*e*) did not in the end affect the design very much. It was found that although the freeboard was only about five inches, waves which seemed quite big ones did not encroach appreciably on the surface. The small splash board provided was more than adequate.

The heaviest part was the tube, which was a six man load. All the parts could very easily be stowed in a ship or loaded in railway trucks, so the demand for portability was met. Assembly time was the stumbling block to the complete fulfilment of the required conditions. "Clover" was assembled entirely by hand and assembly trials under fair conditions were never carried out. An estimate of 50,000 square feet per day for two Field Companies and an Engineer Battalion working under active service conditions was considered optimistic by the Admiralty observers.

*Site for Experimental Work*

The site for construction and trials had to provide as many as possible of the following :—

(*a*) A large area of enclosed water for weathering and "flying on" trials.
(*b*) A sheltered river, lake or bay where assembly could be done, and whence the completed strip could be towed to (*a*).
(*c*) Workshops facilities.
(*d*) Proximity to factories which were turning out the parts.
(*e*) Accommodation for the Naval and Sapper working parties.
(*f*) A Naval base and store.
(*g*) Remoteness and security.

After visiting several very pleasant small harbours in England and Wales, the Clyde estuary was chosen. It fulfilled all the required conditions. Irvine base provided the assembly site. The dour inhabitants of that part of Scotland had become so accustomed to the atmosphere of secrecy which enshrouded the I.C.I. factory and stores there, that security for "Clover" was as sure as it could have been. The manager of a small private dockyard which immediately adjoined the site obligingly offered workshop facilities. Across the river, Lamlash harbour in the Isle of Arran provided an ideal stretch of sheltered water on which "flying on" trials could be carried out. The island was fourteen miles away from the building site, but it was considered that the trip across would provide a very good test for "Clover" under tow, and in sea conditions which were severer than those laid down in the requirement.

*Assembly*

Manufacture of the parts of the re-designed "Clover," and the building of the strip on the bank of the River Irvine, were very much delayed by several setbacks in production and assembly. It was found that the semicircular recess in the baulks needed a special tool, and the Glasgow firm which took the lion's share of the timber work, had to set up a special workshop to deal with them. The firm which was turning out the large steel tubes, and which was alleged to be the only one in the British Isles capable of doing so, had but one suitable furnace. This collapsed after only a small proportion of the tubes had been made. It had to be cooled off and rebuilt. There was a long spell of frost which bound tubes, baulks, nuts and bolts together so that manipulation was impossible. The half-constructed strip after three weeks of intense cold was frozen solid. It was impossible to walk, let alone work on it. In the spring of 1945, the process of assembling the parts, dismantling them again, and modifying some of them was nearly finished.

The method used during this period for assembling "Clover" will be described, as in the end, although there were many other suggestions, it was chosen for use on active service.

The building site was a very slightly shelving beach, sheltered from strong currents by a bend in the river. When the tide was low "under baulks" were brought down from above high water level and laid in position on the dry beach. The tubes were then placed on them. They fell into place very easily, as the recesses in the "under baulks" spaced them exactly. The "top baulks" were then placed over the tubes and rack bolts dropped into place through the "top baulks." At high tide this loosely built frame came afloat, and when thus perfectly levelled, was bolted together firmly. The decking could be fixed at any state of the tide.

The following method was planned for building the strip in a combined operation. It was assumed that in the early stages of the operation a strip 1,000 yd. long and 60 yd. wide would be required. It would be extended later if necessary. Four L.C.Ts. 4, carrying all the stores, would be beached at high tide. As the tide receded they would be left high and dry. Working parties working with vehicles which had been placed ready next to the ramps of the L.C.T.s would unload the stores and lay the baulk and the tube frame. This should be ready by the next high tide, when the frame would be covered with decking and the other appendages fixed. When completely afloat it would be towed out into deep water. The whole operation, it was estimated, would take twenty-four hours. Unfortunately this plan for field assembly was never carried out.

## Crossing the Clyde

*A Difficult Harbour*

A last, one raft, about two hundred feet long, was ready. The temptation to give it a trial run out on the Clyde was too difficult to resist. Such an outing would, in any case, be a useful preliminary to the fourteen mile trip to Lamlash. The Navy got down to the problem of getting this monstrous raft out of the harbour into the estuary. It proved to be a formidable one. When the Scots harbourmaster had first been approached for the use of his harbour for the purposes of "Clover," he had shaken his head and said that this was a "verra deeficult harrbourr." This was put down, at the time, to the personal pride which every harbourmaster takes in the reputation of his channels, and little thought had been given to the problem of getting "Clover" out once she had been built.

The conditions were as follows :—

(*a*) The mouth of the Irvine river is a channel about four hundred yards long and a hundred feet wide. Between extremes of tide the water races through.

(*b*) There is a bar which prevents vessels getting in and out except at high tide. This bar limited the choice of tugs to one local paddle tug and one or two very small screw tugs.

(*c*) These tugs were not powerful enough to tow the "Clover" rafts when once they were out in the Clyde.

(*d*) For safety, the crossing to the Isle of Arran, which might have taken up to six hours, had to be carried out in daylight.

(*e*) The crossing could not be undertaken in bad weather.

(*f*) The assembly site was in a reach of the Irvine which was too shallow for the tugs.

The time, tide, and daylight factors, listed above, limited the occasions on which the rafts could be taken out to three or four days in a fortnight. A spell of fine weather had to coincide with these days. The raft had first to be manhandled downstream to the small tug. This picked up the towlines and towed it down the very narrow channel and out into the Clyde. Here it was taken over by an ocean going tug which had to be ready standing by outside the harbour. There was only one hour of comparatively slack water for all the stages from beach to ocean going tug.

*Trial Run*

There were some very anxious moments when the first raft went out for its trial spin. The party which manhandled it down to the small tug had to hand the towing bridle over to the tugmaster. The naval party manning the raft dropped this very heavy steel cable overboard. Even for sailors it is difficult to recover the free end of a 4-in. steel wire rope from the bottom of 15 ft. of water. There were no winches or other mechanical aids available to help them. This contretemps was a very practical lesson on the necessity for providing good recovery lines on heavy S.W.R. towing cables.

If the delay had been unduly prolonged, there was a risk that this first sample of the airstrip would run aground with the ebb tide and break its back on the unevennesses of the river bed. Fortunately this did not happen and the tug took over tow and started downstream.

Under tow the raft showed a tendency to swing which was most alarming in a channel which narrowed from 140 ft. to 120 ft. There was 20 ft. of spare space on one side where there was a mudbank, and on the other the same distance separated the projecting ends of the steel tubes from the ships moored to Irvine quay. However, controlled by a paddle tug aft, this strange craft squeezed round the bends and cleared the ships safely.

Once outside in the Clyde, with a wind of force five, and waves of 5 ft. amplitude, " Clover " flexed sinuously while her timbers groaned at this unusual treatment. The Sapper crew, who had taken over after the sailors had navigated the harbour, scanned the deck for signs of failure. All was well, " Clover " had " found herself."

*Over to Lamlash*

The stage was now set for the crossing to Lamlash. Special moorings had been laid in the harbour by " Boom Defence," and an accommodation ship anchored nearby for the use of the working parties.

After the experience of the first trial run, arrangements for moving the rafts out of Irvine harbour were improved. Rafts Nos. 1 and 2 were taken across without much difficulty. No. 3 was not so fortunate. The reader will realize that before the rafts could start the trip, they had to be floating freely at the assembly site. This opportunity only came when high tide occurred at a suitable time of the day, when the raft could be moved off the beach and towed to Lamlash during daylight. However, on this occasion the last section persistently refused to come afloat, even at full flood. One corner remained firmly stuck on the mud. It was sheer bad luck. The naval pundit had reckoned without the lowest " high tide " of the year. For two days desperate efforts were made to dislodge the last few feet of one corner of " Clover " from the beach without success. There remained a third and last chance, after which no further opportunity occurred for a fortnight. On the third morning, a supreme effort of pushing and pulling, using crowbars, winches landing craft and launches, was applied, and, inch by inch, the third and last section slipped into the stream.

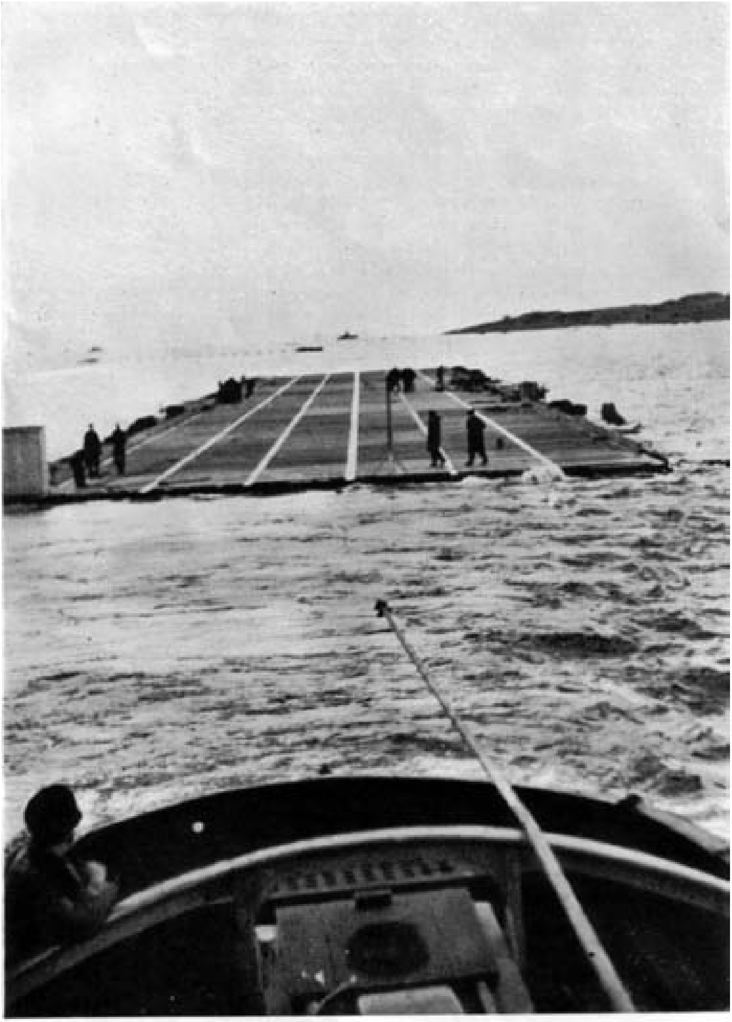


Photo 6.—Under way in Lamlash Harbour.

The Assam Lines Of Communication 6

Photo 7.—A Swordfish touching down,

**A Swordfish Touching Down**

It was not until "Clover" had ridden the waves for several weeks that her languid bending to the movement of the sea ceased to concern her builders. Certainly, as each of the huge floating islands swung round Holy Isle, out of the buffeting of the Clyde and into the stillness of Lamlash harbour, all on board heaved a sigh of relief. (See Photo 6.)

Once inside the harbour, the three sections were joined together, and the completed Austerstrip lay ready for her flying-on trials.

### "Flying On" Trials

The Department of Airfield and Carrier Requirements detailed an officer to carry out these trials. It was a hazardous task, the pilot was limited to 50 ft. for his touch down, and a short landing or an over-run would probably have been fatal both to him and to the aircraft.

Conveniently, the strip swung with the wind rather than with the tide, and no delicate positioning was needed. The first trials were successfully accomplished with the Auster, though there were some tense moments while the pilot made five dummy runs without touching down. After this the courageous fellow volunteered to land a Swordfish. He did this without any difficulty. (See Photo 7.)

These trials provided very little useful information from the point of view of design. The surface of the strip never presented undulations of more than 5 in. amplitude to the aircraft, and the weight of the Swordfish did not visibly depress it. If the trial piece had been long enough, or if arrester gear had been provided, very much faster and heavier planes could have given it a trial. On the other hand, while "Clover" was moored out, valuable information on the damping of the waves, towing forces at various speeds and mooring problems, was obtained. Some of this information is given at the end of this article.

### "Lily"

This story would not be complete without a reference to "Lily," another floating strip which grew up side by side with "Clover." "Lily" was made entirely of steel and consisted of flat topped floating steel boxes, hexagonal in plan, hinged together to form a surface which was articulated in all directions. Several devices were used to damp the effect of the waves. "Lily" has already been given much publicity that it probably is unnecessary to describe it further.

### Conclusion

"Clover" beat "Lily" by a short head in being the first British floating airstrip to land aircraft, but in the end "Lily" was preferred by the experts. In the words of the Admiralty report :—

The operational requirements laid down by D.O.R., Air Ministry, and D.A.W.T., Admiralty . . . have been met by both types of airstrip. They can be maintained in sheltered waters and aircraft can operate safely from them in seas of maximum height 2 ft. (and 30 ft. wave length), in the case of "Lily," and maximum height 4 ft. (and 40 ft. wave length) in the case of "Clover."

On account of mooring, handling and maintenance problems, the type preferred is the modified "Lily". . . .

The question of cost seems to have been given little weight in the assessment of the relative merits of the two strips. The writer believes, though he never saw a statement of costs, that "Clover" was much the cheaper of the two to make. He will remain ready to take up the cudgels on behalf of

"Clover" should the need for floating airstrips ever arise again. New materials are for ever being evolved, and "Clover" Mk. III was only an embryonic stage in the application of principles which pit natural flexibility against the multitudinous hinges of her rival.

After the trials at Lamlash, it was apparent that if further progress in development was as slow as theretofore, the war in the east would be over long before "Clover" could hope to be fully grown. So the tender care of the Sappers was taken away from her nuts and bolts, and she was left at her moorings in charge of the Senior Service.

Many months later and many thousands of miles away from Lamlash and the Clyde, news came that she had been so severely damaged in a storm that no further trials could be done.

## APPENDIX

### Some Figures for "Clover"

These figures are for a landing strip comprising the following :—

Runway—90 ft.by 1,000 ft.
Parking space—125,000 sq. ft.
Maintenance area—45,000 sq. ft.
Total weight—5,200 tons.
Stowage space—500,000 cu. ft.
Assembly time—21,000 man hrs.
Mooring strain in 1½ knots—26 tons.
H.P. of tug to tow at 1½ knots—3,000.

*Surface undulations with a 4 ft. high wave*

| Wave Length | Near Bow | Near Stern |
|---|---|---|
| 40 ft. | 5 in. | ¼ in. |
| 80 ft. | 1 ft. 4 in. | 4 in. |

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# NOTES ON SULPHATE CORROSION

*By* "Pooh"

THE presence of sulphates in soils can cause serious corrosion to concrete, steel and iron. The fact is known by engineers to a greater or less degree ; the cause has been the subject of research by specialists for some years, but their results are not yet conclusive ; the prevention is still a matter of controversy, sometimes bitter.

These notes are the result of a great deal of discussion, some desultory reading, and a limited amount of experience by a "Bear of Little Brain." They are intended to summarize, in terms understandable by the non-specialist, the knowledge that appears to exist in a more profound form in several different places.

### Location of Sulphates

Sulphates are present in most soils and water. Dangerous concentrations, however, are only likely to occur in ground which is to some extent "water-logged" or which does not get washed by a periodic or continuous seepage of water through it. Thus, clay soils in any climate, or any soils in countries with a small rainfall, may contain a sufficient concentration of sulphates to cause corrosion. Sulphates also exist as natural deposits—mostly in the form of gypsum. Sea water contains sulphates in the danger zone. Remains of buildings constructed with gypsum mortar retain a high concentration of sulphates for many hundreds of years.

In England sulphates have given serious troubles in the clay soils of Buckinghamshire and Essex. They exist in dangerous concentrations throughout the alluvial plains of Egypt and Iraq, and in the South of France. In many places, the danger spots are generally known, but they are liable to turn up anywhere.

### Speed of Corrosion

Corrosion by sulphates need only concern the engineer involved in permanent or semi-permanent work. The speed of corrosion naturally depends on a vast number of variables, but is a matter of years rather than months. As a rough guide, it may be taken that, even in the worst cases, serious corrosion is unlikely to take place in less than two years for iron and steel and five years for concrete.

Once it has started, however, it is practically impossible to stop. It is important, therefore, that the engineer should be able to recognize the likelihood of the danger early so that he can take preventative measures if possible during the design stage, but certainly before construction starts.

### Rôle of the Analytical Chemist

The precise concentrations of sulphates likely to cause corrosion are a matter for the soils-chemist. It is sufficient for the engineer to recognize the possibility of their presence. He can then send samples of the suspected soil to the chemist, who will assess the concentration and say, to a technical accompaniment likely to be incomprehensible to all save the most academic of engineers, whether the concentration is dangerous or not.

While on the subject of soil samples, it is as well to note here that, as in most other respects, soils vary considerably in their detailed sulphate content. Consequently, it is important that samples should be taken from trial pits or bores as close to the proposed works as possible, and to their actual depths below ground level. The chemist can be helpful in advising on the size of sample, the detailed method of taking samples and the advisable frequency with which they should be taken.

### Causes and Prevention of Corrosion

Let us now assume that the engineer has been astute enough to recognize the danger and unfortunate enough to have had the chemist confirm it. Let him not fail to consider the most attractive of the courses open ; to go to some other place. It may well save him time, trouble and money if it is possible. Failing this, he must take preventative action. To do this, he must have some knowledge of the detailed processes of corrosion, as far as the details are known today.

Corrosion of iron and steel is known to be an entirely different process from corrosion of concrete, and whereas the foregoing notes have been of general application to both concrete and ferrous metals, those that follow are not, and it is important that the preventative measures are not confused.

### Concrete—Cause of Corrosion

Before considering the cause of sulphate corrosion in concrete, it must be admitted that there is a body of not ill-informed opinion which discounts its existence altogether. Not unnaturally, among those subscribing to this theory is a large proportion of people to whom the idea is inconvenient, but in the absence of any definite pronouncement from the research pundits, some weight must be given to their argument. This always follows the line that there are no examples of sulphate corrosion which cannot be attributed to some other cause. None-the-less, the engineer faced with the danger would be well advised to resist the temptation to join this school of thought.

Research on sulphate corrosion is handicapped first by the length of time it takes to get measurable results and secondly by the apparent inconsistency of examples found on old works, where cases of serious corrosion exist side by side with cases where no corrosion has taken place.

Until recently, many people believed the corrosion was caused by a purely chemical reaction, and inconsistencies were attributed to the presence or absence of an unknown catalyst or to conditions necessary for the reaction being unusually capricious. The chemical theory is discounted—but not necessarily disproved—by the consistency with which corrosion in the presence of sulphates does *not* take place, e.g., satisfactory concrete can be made with sea water, and well finished pre-cast concrete seldom suffers corrosion in sea-water or sulphate bearing soils.

A more plausible theory has been produced which suggests that the corrosion is fundamentally mechanical and acts as follows:—water carrying the sulphates in solution penetrates into the pores of the concrete. The sulphates begin to crystallize out. The crystals gradually grow until they fracture the surface mechanically. More pores are exposed, the liquor flows in and the process continues.

Only long and tedious research will establish whether this theory is in fact correct, but it is a most convenient conception for the engineer to adopt when considering prevention of corrosion.

### Conditions Necessary for Corrosion to Occur—Concrete

From the evidence and speculation summarized above, it has been reasonably firmly established that sulphate corrosion of concrete will only take place if all the following conditions are fulfilled :—

1. Sulphates are present in dangerous concentration
2. Water is present
3. The surface of the concrete is porous with the speculative possibility of a fourth condition that the circumstances are favourable for crystallization of sulphates to take place.

### Prevention—Concrete

The first precaution that presents itself is to drain the site. This is feasible, for instance, in shallow foundations, provided the bearing capacity of the soil is not adversely affected.

Where drainage is impractical, it would be advisable to use pre-cast concrete and not to pour *in situ*. A thoroughly good, smooth finish should be ensured, preferably waterproofed with, say, sodium silicate. Normal or rapid-hardening Portland cement may be used with safety, though special brands for the purpose do exist. The addition of trass to the concrete instead of a proportion of the sand gives the concrete greatly increased resistance, presumably by reducing the porosity.

Aluminous cement (fondu) is immune from attack by sulphates in temperate climates. If poured in hot weather, however, it suffers from some form of deterioration—increased porosity perhaps—which renders it vulnerable.

Chemical treatment of the soil is another possible method of prevention, but the site would have to be sealed off to prevent leaching of the neutralizing agent and inward percolation of sulphates in solution.

### Ferrous Metals—Cause of Corrosion

Sulphate corrosion of iron and steel is fundamentally electro-chemical and thus completely different from that of concrete, though liable to occur in the same localities. Recent research indicates that the electro-chemical action is stimulated by anaerobic sulphate-reducing bacteria.

These little creatures reduce sulphates to sulphides, and liberate $H_2S$ in the process. Exactly how they do this is inexplicable—why, inconceivable.

The sulphide, or $H_2S$, or both, form anode areas on the metal, which induce corresponding cathode areas. Electricity starts to flow and electro-chemical action starts to eat away the metal at the anode areas.

One strange thing is that metals with a high carbon content such as cast iron and mild steel are worse affected than, say, wrought iron, although their carbon content is unaffected. However, no doubt its presence encourages the electricity.

But the most extraordinary aspect of the case is that these bacteria, which exist in most wet sulphate bearing soils, lie more or less dormant until somebody comes along and gives them a nice bit of iron to feed on, when they suddenly wake up and get cracking with a most esoteric and complicated process involving a profound knowledge of electricity, chemistry, bacteriology and sabotage, by the application of which they live and multiply exceedingly.

No thoroughly reliable coating has yet been produced to keep them out.

### Conditions Necessary for Corrosion of Iron and Steel

Serious sulphate corrosion of iron and steel will take place if, and only if, *all* the following conditions apply :—

1. Sulphates are present in dangerous concentration
2. Water is present and stationary or nearly stationary
3. Oxygen is absent
4. The formation of anode areas on the metal is electrically possible

### Prevention—Ferrous Metals

As with concrete, one solution is to drain the site. Another possibility in the case of iron or steel is to aerate it. The suggestion of filling water-main trenches in affected areas with sand or gravel has been made. Chemical treatment of the soil to neutralize the sulphates is a conceivable treatment but would be accompanied by similar difficulties to those with concrete.

Experiments are being carried out with artificial anodes in order to make the metal to be protected into a hundred per cent cathode area ; and lastly, concrete can frequently be substituted, provided the precautions described above for concrete are taken.

Bituminous or similar coatings do not give protection but may delay corrosion to some extent, as may the use of iron with a low carbon content.

### Conclusion

To sum up, sulphates constitute a danger to concrete and iron and steel. Early recognition of their presence may save much time and money. A hundred per cent protection cannot, at present, be assured ; but in many cases a few simple precautions are possible, which will minimize the danger of serious corrosion.

*Note*

E.-in-C. reports that there are important instances where sulphate action has seriously damaged semi-permanent mild steel pipelines in considerably less than two years. For example, sulphate erosion caused great damage in about twelve months to a part of the Suez-Port Said oil pipe laid during the war. At this point in the line conditions were exactly as laid down by the author. The damage was fully expected when the pipe was laid, but it was impossible at the time to take more than perfunctory precautions. Sulphate erosion also occurred in some parts of the Western Desert pipeline in under two years.

(Editor.)

# AIR ENTRAINED CONCRETE

" ANONYMOUS "

MOST construction engineers will probably have read, or at least have heard of, the latest American development in concrete practice, known as " air entrainment " ; but unless they have made a special study of the subject, they may be rather hazy as to what it is about and what the implications are. The following notes are designed to give a brief outline of this new development.

1. *Definition*

Air entrainment is the *intentional* introduction into the concrete of a large number of very small " discrete spheroids " of air. It is not to be confused with the unintentional and undesirable air cavities or capillaries formed by the evaporation or bleeding of excess water that has not combined chemically with the cement. The discrete spheroids are not interconnected and do not in any way contribute to the permeability of the concrete.

2. *How it is Obtained*

A very small proportion of an air entraining agent is milled in with the cement in manufacture, or added to the cement at mixing. Proportions vary according to the agent being used ; percentages for two typical agents are ·03 per cent and ·10 per cent of the cement by weight. Numerous agents have been discovered, but so far the most satisfactory as regards cost and results is preneutralized Vinsol Resin, a very cheap by-product of the Hercules Powder Co. of U.S.A., and, incidentally, a very effective soil stabilization agent. The latest American opinions on the whole prefer the admixture of the agent on site, since continuous control of the percentage of air entrained can thereby be more effectively maintained.

3. *Advantages*

(*a*) Increased durability, caused by the ability of the tiny air voids to act as reservoirs in absorbing the expansion of free uncombined water in the concrete and thereby reducing the internal stresses which normally cause disruption. A useful aspect of this is the high resistance to weathering imparted to the concrete, especially in conditions of alternate frost and thaw.

(*b*) Good resistance to the scaling action of salt or calcium chloride when used for ice removal on concrete roads.

(*c*) A good surface finish to the concrete can be more readily obtained.

(*d*) Less segregation in handling. This might imply that the newly mixed concrete can be transported further in non-agitating vehicles, but this fact has by no means been established.

4. *Disadvantages*

(*a*) Loss of strength. This is due to the fact that, everything else being equal, the air entrainment affects the strength, the same as if, instead of air, an equal volume of water were added. The effect is that, if the water/cement ratio remains constant, the compressive strength decreases about six per cent for every one per cent increase in air entrained ; however, workability is considerably improved by air entrainment and so the water/cement ratio can be reduced somewhat (although by no means to the same extent that air is added). Therefore, for equal workability, it is found in practice that the compressive strength decreases three to four per cent for every one per cent increase in air entrained.

The figures below show the effect of 5 and 10 per cent air entrainment on a 1–2–3½ mix by weight, with a compressive strength of 5,300 lb./sq.in. at 28 days.

| | 5% air entrainment | | 10% air entrainment | |
|---|---|---|---|---|
| | w/c ratio unchanged | workability unchanged | w/c ratio unchanged | workability unchanged |
| Compressive strength at 28 days | lb./sq. in. 3,700 | lb./sq. in. 4,300 | lb./sq. in. 2,400 | lb./sq. in. 3,300 |

To obtain the maximum benefit from the advantages without too great a loss in strength, the degree of air entrainment should be from three to six per cent, depending on the nature of the construction and effectiveness of control.

(*b*) Difficulty of control. Up to date, it has not been found possible to predict with sufficient accuracy the degree of air entrainment that will be obtained for a given proportion of air entraining agent. The amount of air depends on too many factors ; the shape of the aggregate, the proportion of sand, the proportion and nature of the cement and the length of mixing time all affect it. This means that tests must be carried out continuously and the mixer operator must exercise great care that the factors under his control remain as nearly as possible constant.

If air entraining cement is used, i.e., cement with which the agent has been milled in manufacture, the engineer will find it even more difficult to control the degree of air entrainment. This is the main reason why modern American opinion favours the admixture of the agent on the site.

5. *Present position in U.K.*

The following remarks of the Concrete Section of the Road Research Laboratory are given with the permission of the Director :—

" In this country, very little work has been done on air entrainment. Our use of drier concrete, the application of less work to the surface of the concrete, and the fact that our winters are, in general, much less severe than those in America have all helped to reduce the scaling troubles relative to those in U.S.A. and the need for research on these lines has therefore been less urgent. We, here, feel that the solution of such troubles that do occur lies in the use of a thoroughly compacted, high quality concrete, free from surface laitance, and this result can be achieved without difficulty, and without the use of admixtures with the compacting and finishing machines now on the British market.

There has been a good deal of damage done by frost to precast concrete kerbs and we are now investigating the possibility of using an air entraining agent as a means of increasing the resistance of kerbs. No results are yet available, however."

The above remarks refer purely to the use of air entraining agents for increasing resistance to frost damage. The R.R.L. further states that there may be conditions, as suggested by recent work in America, in which the use of agents will increase the resistance of concrete to certain other deleterious influences other than frost, such as the presence of unsound aggregate or of chemically active soil waters. Further research is required to establish whether this is, in fact, the case. If it proves to be so, increasing interest will doubtless be paid to the use of air entrainment in this country.

# AMERICAN AND BRITISH ENGINEER ORGANIZATION AND METHODS IN PERSIA

*By* COLONEL R. E. WOOD

## INTRODUCTION

1. It is difficult to compare the American Works organization with our own in Persia since the whole basis was differently conceived. We employed small supervisory staffs, C.R.Es. and Works Secs, who controlled large quantities of civilian labour or contractors, whereas the Americans had a considerable military engineer force. Where our military labour was employed some comparison is possible, though our engineer units—Art. Wks. Coys., Mech. Equip. Op. Coy. etc.,—were not an integral part of the Works organization and not under the local engineer commander for all purposes as in the American Army. In road construction, in particular, the two Corps of Engineers were, for the last two years of the war, largely complementary, the type of work undertaken having been determined by the resources of each.

2. I therefore propose, before attempting to draw any comparisons, to outline in Part I, the American Engineer organization which existed in Persia, in case it differed from that elsewhere. This is very probable since they claim considerable elasticity both of lay-out and method.

## PART I—AMERICAN ORGANIZATION

3. *Units*

The American aim in the Persian Gulf Command was the execution of all work by military labour. In only rare cases did they employ contractors, and civilian labour was only used on specific tasks under close military supervision. Three engineer construction regts., each nearly 1,200 strong, were included in the force. One (coloured) was a General Service Regiment, chiefly employed in S. Persia, on camps, maintenance and local road-work. The other two (white) were Special Service Regiments, in which nearly every man was a tradesman and an expert at his job. The proportion of N.C.Os. and high-grade artisans and technichians, whose pay and rank correspond to that of N.C.Os., was very high. Thus out of a total regimental strength of 1,180, 250 were of rank equal to Staff-Sgt. and above, and there were only 135 Privates. Recruitment was direct from civil sources, chiefly by selection from men employed on military and civil works—airfields, camps, roads, etc.—by the Corps of Engineers. The large percentage of senior N.C.Os. and highly paid grades was an inducement for the best men to enlist. It is of interest to note that the average age of one engineer regiment was thirty-eight.

In addition, there was a Water Supply battalion and an Engineer Depot, which acted as stockholder for all engineer plant, transport and equipment, and contained the main engineer workshops.

4. *Lay-out*

Each regiment was allotted an area, not necessarily conciding with administrative boundaries, to suit its establisment, which consisted of six Construction companies organized in two battalions, and a H.Q. and Service company intended to be at Regimental H.Q. In practice this Service company, which contained the top technicians, was parcelled out amongst the Construction companies. In addition to the main camps, which were sited to suit "Aid-to-Russia" convoys, and which normally contained one engineer company, there were road camps every forty miles or so on the main Khorramshahr—Kazvin highway, each housing a half-company with workshop accommodation. The strength of each company was about 180 men.

5. *Administration*

In each administrative district there was a District Engineer on the staff of the District Commander. He was a staff officer with no executive powers, but communicated the orders of the District Commander to the senior engineer officer—i.e., Regimental or Battalion Commander—and acted as liaison officer between the administrative staff and the engineers.

Each Construction company was self-contained as far as domestic transport, equipment and staff were concerned but discipline was exercised through Regimental and Battalion Commanders. Companies located in main posts were under the Post Commander for certain local administration. One company officer was nominated as Post engineer, who took his orders from the Post Commander regarding local engineer requirements and was responsible for all engineer maintenance (incl. water supply) in the Post area. He corresponded to our G.E. and drew such staff and tradesmen as were required from his own company.

Administrative approval for new works, including major road-works, was communicated through staff channels. Thereafter technical control was exercised by the Chief of Construction, H.Q., P.G.C, through Engineer Regimental Commanders.

6. *Equipment*

The Americans were lavishly provided with electrical and mechanical plant and equipment of all kinds, especially earth-moving and road-making equipment. This was the result of good forward planning, thorough recce by advance parties over several months, and the immense home resources which were available. It may be noted that most of the initial supplies were commercial models, non-standard, which led to some later difficulties over spares.

All equipment was pooled, held and accounted for by the Engineer Depot at the base, and allotted by the Chief of Construction to engineer units as required. The original maintenance system was 1st line by the operating unit (Company), 2nd line by Regimental H.Q. (Service Company) 3rd and 4th line at the Engineer Depot. Distances in Persia were so great that this system was subsequently modified—first, by splitting up the Engineer Regimental Service Company, as mentioned in Section 4, and later by detaching Workshops personnel from the Engineer Depot, with Mobile Workshop trucks, to regiments, and even to companies. A wing of the Engineer Depot Workshops was also set up in North Persia, with the title of Engineer Maintenance Company, operating direct under the Chief of Construction. By this decentralization, companies were able to carry out 1st, 2nd and 3rd line work and even 4th line on occasions.

With road plant, two operators were allotted to each machine and were responsible for daily maintenance and periodical servicing, though the latter was normally carried out by a special Mobile Grease Unit.

7. *Transport*

Much the same remarks as above apply to transport of which the Engineers had a large pool. Tippers, dumpers and G.P. trucks alike were controlled, handled and maintained by Engineers. By local arrangement, the Transport Service repair organization having its hands full, maintenance by Engineer personnel included 4th line. Engineer transport actually engaged on road construction work invariably carried a distinguishing flag on the driver's cab, to ensure priority of passage when convoy traffic was heavy.

8. *Stores*

The procurement and bulk holding of engineer stores was a function of the Supply Division of the American Staff, whereas engineers worked under the Operations Division. The Chief of Construction was responsible for communicating his requirements to the Supply Division, and for the subsequent allocation of stores when obtained. Bulk stores were held by the Engineer Supply Depot (a Supply unit) and drawn on direct indents by engineer units against the Chief of Construction's release orders. Local purchase of engineer stores was done through the Supply Division's Local Purchasing Offices. There appeared to be little essential difference from our procedure, since the engineer stores section of the Supply Division was staffed by engineers.

9. *Tasks*

The rôle of the Persian Gulf Command was the delivery of "Aid-to-Russia," a service task with no combat troops, and comprised the construction (as required) and operation of one railroad and one highway. The Chief of Construction had three primary tasks :—

(*a*) Port and Harbour construction at Khorramshahr
(*b*) Camps on both routes
(*c*) Highway Khorramshahr—Andimeshk (180 miles)

Tn. construction was quite separate under the Military Railroad Service.

In addition American engineers assisted, though the responsibility remained British, in the upkeep of the highway Andimeshk—Kazvin (460 miles). Officially, assistance was rigidly defined—in practice, co-operation was whole-hearted, and few requests met with even hesitation. By the time this American assistance was forthcoming, towards the middle of 1943, British engineers had a passable road in operation and about fifty per cent was bitumen-carpeted. The subsequent division of work was that the Americans, with the resources of plant, undertook all reconstruction and realignments and maintenance of approximately fifty per cent of the total length, while the British, with the greater experience of contractors and civil labour, undertook carpeting, drainage, bridges and retaining walls. It is a tribute to the elasticity of both organizations that much over-lapping of boundaries and many local rearrangements were achieved without friction.

## Part II—Comparison with British Organization

10. *Manpower*

In making comparisons between the respective engineer organizations the first and most important factor, on which so many of the differences between the two depend, is that of manpower. Disregarding operational commitments, with which the Americans had no concern, the British engineer force, at its maximum, available for Works Services in Persia was approximately 2,000 men—4 C.R.Es. ; 11 Works Secs. ; 6 Sections of Mech. Equip. Op. Coys. ; 1 Engineer Battalion, and 3 Art. Wks. Coys.—and over fifty per cent of this was withdrawn during the first half of 1943. With this force the British engineers had to carry out much the same amount of camp construction as the Americans and maintain 2,100 miles of road on routes other than those given in Section 9. The American advantage in this respect was thus something like four to one.

11. *Officers*

The junior American engineer officers were largely specialists, employed in the field in the same capacity as in civil life. The small percentage of regular officers were mostly in staff or high engineer appointments.

The liaison between the U.S. Corps of Engineers and the civil engineering faculties is much closer in peace-time than we achieve in Britian and the following examples are worthy of note :—

(*a*) Officers of the Reserve (corresponding to our Supplementary Reserve) can be called up in peace-time not merely for training but for considerable spells of service, when work for which they are specially suitable arises.

(*b*) Certain engineering projects in the States involving Federal, as distinct from State, funds are handled by the Corps of Engineers, whose officers thus get experience of the planning, design, administration and execution of large works, both military and civil. With national resources at their back, Military engineers have opportunities of research and experimental work, both in design and construction, frequently of value to the engineering world as a whole. Many military engineers have been awarded degrees and diplomas by the civil engineering associations as a result of work carried out by them, both at home and abroad.

(*c*) A manual entitled *Military Roads in Forward Areas*, on which the American road organization in Persia was largely based, was published in 1941, by the Highway Division of the American Society of Civil Engineers. The Committee which drew up this manual consisted of two regular and one reserve officer of the Corps of Engineers, one regular officer of the Air Corps and two civil engineers.

In the Royal Engineers it was the exception to find officers employed on tasks for which they had special qualifications or experience. In a country where a large proportion of the work was the construction, improvement, and maintenance of roads, less than ten per cent of the R.E. officers had previous experience of road work and less than five per cent had ever handled mechanical equipment.

Any conclusion to be drawn must take into account the overshadowing effect of manpower—American civil engineers were plentiful, and large numbers had experience of the type of work, country and climate met in Persia. The R.E. officer appears to be more adaptable and better at improvisation than his American counterpart, and the latter, though quick to learn from his own mistakes, is disinclined to be guided by the experience of others which might have enabled him to avoid them. It is of interest to note that the American engineer officer was allowed less initiative and responsibility, and was subject to more centralized control, than his British counterpart.

The lessons to be learned as far as training of officers is concerned are better liaison with the civil engineering world, both to improve the peace-time training of the regular officer and to assist the better allocation of civil engineers in war, and the necessity for the Royal Engineers to specialize in certain forms of engineering, e.g., road and airfield construction, in which civil experience and resources are limited. Much value could be gained by the exchange of officers with the American Corps of Engineers in peace-time, a step which I believe would be welcomed.

12. *Other Ranks*

Many of the remarks about officers above apply equally to other ranks. There is little wrong with the training of the personnel in the Establishment for Engineering Services, but there were not enough of them, and the lack of men with road and mechanical equipment experience was particularly noticeable. Here the American method of recruitment commends itself. I would advocate the formation of complete Works Sections, as was done at the beginning of the war in raising General Construction companies, from County and Borough Councils and civil engineering firms. A large supplementary reserve for the E. for E.S., as existed for Transportation, is a peace-time necessity.

13. *Planning and Organization*

A noticeable feature of American methods is the time spent in careful and detailed forward planning. In the Persian Gulf Command the commander and many of his senior staff were engineer officers and the engineer executive did not have to resist constant pressure to start work before this planning and organization were complete. No road work was started, for example, until camps for the units concerned were ready. In Persia, conditions were ideal for this method, as the British were already in the country and capable of keeping roads open, railways working, and ensuring the Americans reasonable supplies of stores until they were ready. Reports from other theatres, notably the Pacific, show, however, that the American planning there was equally efficient and based on a sound appreciation and reliable intelligence, enabling them to make a rapid start.

British planning in Persia was primarily operational. The engineer follow-up, expressed in the comprehensive title "Aid-to-Russia", appeared to have been insufficiently appreciated, though the overshadowing factors of manpower and other resources explain many shortcomings. Engineer intelligence was inadequate, methods of construction, both for camps and roads, had been insufficiently foreseen, and the credit for the success achieved must go to the resourcefulness and adaptability of the R.E. on the spot. I do not think American engineers would have achieved the same initial effort in these conditions, but on the other hand, I do not think they would ever have permitted the conditions to arise. Our standards of planning have improved and it is becoming better realized that in engineer, like other military, enterprises, policy must not outrun resources.

An interesting point is the position of the British C.R.E. Works who had no American counterpart. His duties as technical adviser to his District or Sub-Area Commander were carried out by the District Engineer (see Section 5), while his executive powers were exercised by the Regimental or Battalion Commander. The latter had all engineer troops in his area under his direct command. The Americans claim that by having a technical staff officer there is much better liaison between engineers and District staffs than would be achieved by an engineer commander attached to the staff. In our case the C.R.E. Works is not even attached and liaison becomes very much a matter of the personal relations between the local commander and his staff on the one hand and the C.R.E. and his staff on the other. The American higher organization also included the senior engineer staffs as part of the H.Q. The American system eliminated the necessity of one man serving two masters, but appeared to contain elements of friction between the District engineer and the local engineer commander. My view is that the possible advantages are insufficient to merit its adoption.

The American maintenance organization which has already been described, differed little from ours in its inception, and encountered much the same difficulties. It is to be noted that American manpower enabled them to decentralize maintenance at the moment when we were (to our detriment in Persia) compelled to centralize and transfer valuable R.E. personnel to R.E.M.E.

14. *Equipment and Transport*

Enough has been said in Part I to show that the American engineers were much better off than the British. Comparative figures are not given since numbers and conditions of employment varied greatly. It is of interest to note that American machines taken over by us on loan in 1945, had worked nearly twice the number of hours of similar machines already in our employ. This is chiefly attributable to the manpower factor—two operators per American machine and better local workshop resources.

One opportunity of using an American equipment bridge occurred, on the Karun river, where a Class 25 pontoon bridge was installed in July, 1944, and carried a great deal of heavy traffic. It did not compare favourably with British models. As a front line bridge it had the disadvantage of single bays which meant construction must normally be by " forming-up " or " booming-out." Rafts could be built but joining together was a matter of great difficulty, as was also the replacement of damaged sections.

As a L. of C. bridge its disadvantages over our Class 24 bridge were more pronounced. It had no long landing bays and the sliding bays gave less play, so that tidal ramps were not only difficult to construct but required very frequent adjustment of trestles. The Karun bridge had to be cut daily for river traffic, and no satisfactory solution could be achieved with the American equipment. Mark V pontoon raft connectors were introduced with improvised attachments to the American roadbearers and this worked satisfactorily. Parts and fittings varied considerably in strength and quality of workmanship. A major fault was in the bulkheads which carried the bollards for anchor ropes, and had little longitudinal strength. The Karun runs at six to seven knots at certain seasons of the year, and anchor ropes calculated for this current caused the bulkheads to shear at the point of attachment to the sides of the pontoons. The introduction of longitudinal struts was necessary to prevent this.

## Part III—American Methods

15. *Road Construction*

The Americans had many road engineers, both officers and other ranks, with experience of road construction in conditions almost identical with those in Persia. Training in soil physics and chemistry enable them, with Field laboratory equipment, to determine rapidly the treatment required by the existing base and the type of fill to be used. Base stabilization and consolidation were of the first importance and much effort was concentrated on these. The result was that a light specification could be adopted for the protective and wearing surfaces. Soling was never used, reliance being placed on the consolidation and compaction of the existing soil. To assist in this, traffic was frequently run over a newly consolidated base for many days, or even weeks, before surfacing was commenced. The principal form of surfacing was " inverted penetration " which, as its name indicates, consisted in spraying bitumen to the required thickness and rolling in a carefully graded gravel.

The methods employed are fully described in the manual previously mentioned—*Military Roads in Forward Areas*—No 23. in a series of Manuals of Engineering Practice published by the American Society of Civil Engineers. This manual is well worth studying by all R.E. officers concerned with roadwork. A great variety of equipment is needed and this had been provided.

The British had perforce to take risks over base consolidation and preparation, lacking the necessary equipment in sufficient quantity, and rely on a heavier surfacing, for which a one inch sand carpet was normally used. Generally, the risk was justified though some stretches failed and were subsequently reconstructed by the Americans.

The standard of road achieved was adequate for its purpose, but there was a regrettable tendency on the part of the Americans to concentrate on alignment and surface, with the object of speeding up traffic, and neglect other factors. Drainage on their sections was elementary in the extreme, massive embankments were constructed with quite inadequate culverting and there was a general tendency to rely on their resources of equipment to make good damage by weather rather than take initial steps to prevent it. This is an example of the American trait referred to in Section 11—disinclination to be guided by the experience of others. Their first winter was a mild one and the advice of British engineers (in their second winter) was too lightly disregarded. Several fine pieces of American roadway were destroyed in the late autumn of 1944, as a result—after the American engineer resources had been withdrawn, but while " Aid-to-Russia " traffic was still running.

Many realignments, both major and minor, were carried out to eliminate difficult stretches and dangerous bends, and visibility on many blind corners improved. As mentioned in Secion 9 American engineers waived official boundaries when necessity was obvious and the utmost co-operation was achieved.

16. *Camp Construction*

The Americans disregarded units as such and all living accommodation was constructed to a standard layout. Each section of a camp catered for about 250 men—eight to ten sleeping huts, recreation hut, mess hall and kitchen, ablution hut and latrines. In large camps, sections were in pairs, with roads between pairs. Officers' quarters were in blocks of eighteen to twenty, with a small " common room " and sanitary annexe to each block. Unit messes were rare and officers' messing was normally centralized in a well-founded club. No separate accommodation was provided for Sgts. All huts were completely fly-proofed.

The average height of huts was 1 ft. 6 in. less than ours, and in taking over American accommodation for our purposes the number of men in a living hut had to be reduced by fifteen to twenty per cent to fit our scales of floor space and cubical contents. In the hot weather the Americans used air-conditioning throughout, so that cubical content was of less importance, but in the winter huts were overcrowded and lacking in ventilation by our accepted standards. Ablution facilities were also less and latrines consisted of long banks of seats with no partitioning. Officers' sanitary annexes contained wash-basins, showers, urinals and latrine seats all in one room. The standard of fittings—lavatory basins, w.c. pans and water-borne sewage in most camps—contrasted strangely with complete lack of privacy.

Every major camp had its soldiers' club with theatre/cinema, restaurant, snack bar, and library well supplied with books and papers. The theatre stage was adapted for either indoor or outdoor performances but dressing-room accommodation was very cramped. This is probably explained by the fact that most American entertainments were either large scale Army productions—bands of thirty to forty—or single star shows—Lily Pons, Nelson Eddy, etc.—with one or two supporters.

Kitchens in clubs and messes were well found—first-class cooking equipment, wash-ups, refrigerators and, in hot stations, underground store-rooms.

Inspection of American huts suggested that much lower factors of safety for timber than ours were permitted in the design of roofs, or, alternatively, the poor quality of local timber was not appreciated.

Internal finish was good, water and sewage systems usually comprehensive, and good roads, mostly bitumened, were provided in all camps. Surface drainage was, however, usually elementary and the American habit of driving trucks everywhere, even to the doors of huts, reduced many camps in winter to a sea of mud. It is also noteworthy that, with amenity standards generally higher than ours, swimming pools were rarely provided.

I have insufficient knowledge to comment on the American organization of camp construction, but judging by the rate of progress seen, this was up to their usual high standard.

(17) *Comparison of American and British Methods*

R.E. officers were quick to appreciate the advantages of American methods of road construction, and during 1944, we adopted these methods when circumstances permitted on roads other than the joint "Aid-to-Russia" route. Where plant was available the base was treated in the American way and American type surfacing was successfully carried out by our contractors and by our one Mech. Equip. Operating unit. In 1945, a Works Section was converted into a Mobile Road Construction Unit, with a percentage of Persian civilian operators, specially trained, and carried out reconstruction successfully with borrowed American equipment. An improvement on the American surface was found to be the use of a coarser gravel which was especially suitable on hill sections. The deduction is that, with the same resources of manpower and equipment, British road engineers are as capable as the Americans. They certainly appear to understand drainage better.

The great advantage of the Americans in camp construction lay in the standard lay-out and this cannot be too strongly stressed. We continue to build for specific units though it is rare to find camps occupied by these units in the end. The constant delays to which engineers are subjected by changes of plan, additions, alterations in strength of units, etc. would be avoided if standard camps were adopted.

In design I consider we were superior; in workmanship, through using civilian labour with insufficient skilled supervision, inferior to the Americans. Their higher standards in fittings and amenity measures were mainly a matter of cost and availability of stores. Initially, while dependent on supplies from us, they loyally accepted our standards, but later, as their own supplies became available, these were improved.

18. *Conclusion*

I have made recommendations on various points above and these I do not intend to recapitulate. The main lesson to be learnt from the Americans is the close affiliation necessary between the military and civil engineer in peace-time, to ensure our adequate training in peace and our proper allocation of manpower and resources in war. To call civilians to our aid in war-time is not alone sufficient, since many civil engineers of high standing are not suddenly able to appreciate all the military factors involved, and unjustified criticism of military "red-tape" is often heard as a result. I foresee the necessity for the addition of officers to the E. for E.S. in peace-time, both Regular and Supplementary Reserve, and, in the case of the regular officer, the abandonment at some stage in his career of the theory of inter-changeability between combat and works duties.

Finally, although as the British C.E. in Persia I was in the position of a poor relation for the last two years of the war, I am quite unable to harbour the traditional feelings of poor relations towards rich relatives, with whom contact was both pleasant and stimulating.

## MEMOIRS

### COLONEL E. M. BURTON

EDMUND MERCERON BURTON, of Farnham, Surrey, who died at 49, Redington Road, N.W.3, on 2nd April, 1948, was born on 27th July, 1860. His death removes one of the few remaining links with the days when the soldier went to war in a scarlet tunic (even in a tropical climate) and battles were fought in squares with the front rank kneeling down and the rear rank firing over their shoulders.

Colonel Burton was educated at King William's College, Isle of Man, and the Royal Military Academy, Woolwich, and was gazetted to the Royal Engineers in 1879. He took part in the operations for the suppression of Arabi Pasha's Rebellion in Egypt in 1882/3, and was a member of the Palmer Search Expedition under Sir Charles Warren, which succeeded in tracing the murderers of Professor Palmer and his companions in the Sinai Desert. Lieut. (as he then was) Burton prosecuted the criminals, who were publicly hanged at Tanta. The remains of Palmer and his companions were brought to England and interred in the crypt of St. Paul's Cathedral. This expedition was described in *Man Hunting in the Desert* by Captain Alfred H. Haynes, R.E., one of the members of the Expedition. (London, Horace Cox, 1894.)

Colonel Burton took part in the Sudan campaigns of 1884/5, and was present at El-Teb and Tamenieb, where the dervishes charged the squares with fanatical bravery and actually succeeded in breaking the corner of one square temporarily, although armed for the most part only with spears, shields of hide and heavy double-edged swords of the Crusader pattern. Burton took part in the Gordon Relief Expedition, and was selected, no doubt partly on account of his fine physique and great powers of endurance, for the party that made a forced march across the Bayuda Desert in the final attempt to reach Gordon at Khartoum, only to find they were two or three days too late. Burton was awarded the Queen's Medal with three clasps, the Khedive's Bronze Star, and the 5th Class of the Order of the Medjidie, and was also mentioned in dispatches.

He served in the South African War, 1899–1902, and was awarded the King's and Queen's Medals and was mentioned in dispatches. He was C.R.E. at Pretoria from 1908 to 1910, retiring in the following year. He volunteered for service immediately on the outbreak of war in 1914, and was employed throughout the war as C.R.E. South Wales District.

Colonel Burton married, in 1896, Zoë Julia, third daughter of William Angerstein, of Weeting Hall, Norfolk, and grand-daughter of Sir Henry Ainslie Hoare, 5th Baronet, of Stourhead, Wiltshire. Mrs. Burton died in December, 1940. Colonel Burton is survived by his three sons and two daughters.

H.M.B.

**Colonel A.T Moore CBE**

## COLONEL A. T. MOORE, C.B.E.

ARTHUR TREVELYAN MOORE was born at Mount Aboo, in India, in 1866, and was the son of Surgeon-General Sir William Moore, K.C.I.E., Q.H.P., of the Indian Medical Services. He was educated at the Imperial Service College at Westward Ho! and the R.M.A., Woolwich.

He was gazetted into the Corps as a Lieutenant in 1885 and after the normal two year course at the S.M.E. was posted to the 12 Fd. Coy. at the Curragh in 1887. Three years later the company was moved to Portsmouth and a few months later Moore was ordered to India.

He arrived in Bombay in April, 1891, and was posted to the Bengal Sappers and Miners at Roorkee, being immediately detailed for a course of instruction in the Govt. Telegraph Dept., after which he was in charge of sub-divisional telegraphs at Sialkot and Rawalpindi.

In September, 1892, he proceeded with the Isazai Field Force as Supt. of Field Telegraphs and ran a line from Haripur to Derbend, a distance of 28 miles, in six days, for which he was specially commended by Lord Roberts and other high authorities. He contracted cholera on this expedition but recovered, and after a month's sick leave was posted to the Military Works Dept. at Rawalpindi, where he was placed in charge of special defence works.

He remained at Rawalpindi till September, 1894, when he was posted to Muree in charge of the Muree Waterworks, which were nearing completion, and early the next year he was also placed in charge of the work of converting the Depot Barracks into the H.Q. Offices for the Punjab Army. For this work, as well as for a report which he compiled on the Murree water supply system, he received a special commendation from the C-in-C. the Punjab Army.

In 1895, he was promoted Captain, and the following year he returned to the U.K. on one year's leave, but transferred to the Home Establishment after eight months and was posted to Athlone. Two years later, in 1898, he was posted to the Training Battalion at Chatham, and in 1901, he commanded the representative R.E. Company at Queen Victoria's funeral.

In March, 1902, he was posted to command the 24 Fortress Coy. at Malta, but returned home in September of the same year to take over the duties of Secretary of the R.E. Institute at Chatham. At that time this appointment was held by a serving officer, and the present title of Institution of Royal Engineers was only adopted in 1923, when a Royal Charter was granted. He held this appointment for five years and during this time was present on the occasion of the inspection of the Corps, in 1904, by H.M. King Edward VII, as Colonel-in-Chief, and again the following year when His Majesty unveiled the South African War Memorial.

On vacating the appointment of Secretary, R.E. Institute, in 1907, he was posted to the Depot Battalion at Chatham and the following year he was appointed as Brigade Major and Secretary of the S.M.E., which post he held until he was promoted Lieut.-Col. in 1911, when he was posted to Aldershot as C.R.E. Lands. He was then ear-marked for the appointment of C.R.E. Cavalry Division on mobilization. This appointment, however, lapsed in April, 1914, when the Cavalry Field Squadron was introduced.

On the outbreak of war Moore was appointed C.R.E. 7 Division which was commanded by Maj.-Gen. T. E. Capper. The division embarked from Southampton early in October, 1914, and were landed at Zeebrugge to cover the withdrawal of the Antwerp Garrison. A week later they had withdrawn to Ypres and for the next three weeks the division was engaged in heavy fighting defending Ypres. Early in January, 1915, Moore was ordered home with a view to proceeding to Gibraltar.

Moore had kept a very useful diary of his time in France and Belgium as well as notes of his general record of service. These notes have been freely used in compiling this memoir and it is obvious from them that he did not always see eye-to-eye with his divisional commander. Although he does not himself say so, this fact may have had some bearing on his transfer to Gibraltar. He was, however, mentioned in dispatches for his services as C.R.E. 7 Division.

He arrived at Gibraltar on 24th January, 1915, and took over duties as C.R.E. and acting Chief Engineer. He was promoted to substantive Colonel on 1st April, 1916, with an ante-date to 15th December, 1914, and took over officially as Chief Engineer in February, 1917. In September, 1918, he was granted one month's leave in the U.K.

On 12th November, 1918, the day after the armistice, Moore returned to Gibraltar overland, via Paris, and continued his duties as Chief Engineer, which included various other appointments, such as member of the Board of Sanitary Commissioners, chairman of the Cemetery Committee and member of the Board of Trustees of the Cathedral. Other duties included chairmanship of a committee to regulate food prices and another to report on the administration of the markets. He was also secretary and field master of the Royal Calpe Hunt, and President of the Polo Club. It will be realized from this rather formidable list of activities that his time at Gibraltar was fully occupied, and for his services here he was awarded the C.B.E. in June, 1919.

In August, 1919, he again came home for two months' leave and only returned to Gibraltar, for about six weeks, to hand over to his successor. He arrived home again on 9th December, 1919, when he was placed on " half pay " and finally retired on 26th January, 1920.

He was married in Ireland on 27th February, 1889, to Constance Elizabeth Kennedy the daughter of William Kennedy, who died in 1946. He had three daughters.

He and his wife lived a most devoted and happy life and his career in the Army was often subjected to his desire to serve in appointments where his wife could be with him.

E.G.G.K. writes :—" The two things that stand out in my memory of him are:—(*a*) the delightful friendliness of A.T.M. and Mrs. Moore to the Y.O's. when A.T.M. was Brigade Major. She, especially, was so good at " Gym " Dances etc., and they were always getting up things for the Y.O's. I put it down to their having themselves married so young and been so happy in their marriage.

(*b*) The talk he, as B.M., gave to the batch collectively when it was about to leave Chatham and during which he strongly advised against marrying young or as a subaltern. Though he meant every word of it he couldn't restrain the twinkle in his eye and was obviously thinking how young he himself had married and how glad he was of it."

J.M. says :—" He was the most quiet and retiring of men and modest almost to excess. It was only after his death that I found how much his neighbours and all classes of the village thought of him. His modesty prevented him from taking a position in the neighbourhood for which he was very well qualified."

After he retired his main interest was hunting and he was on the Committee of the Garth Hunt. He kept a small herd of dairy cattle and also took an interest and active part in the British Legion and Boy Scouts.

He died on 13th January, 1948, at the age of 81.

C.C.P.

## BOOK REVIEWS

### HISTORY OF WORLD WAR I, 1914–18
### MILITARY OPERATIONS IN FRANCE AND BELGIUM Vol. V

Compiled by Brig.-Gen. Sir JAMES EDMONDS, Kt., C.B., C.M.G., Hon. D. Litt. (Oxon.), R.E. (Retd.) and Lieut.-Col. R. MAXWELL HYSLOP.

(Published by H.M. Stationery Office. Price 30s. 0d.)

This volume, which covers the last forty-seven days of the 1914–18 war on the Western Front from 26th September to 11th November, 1918, really completes the great work of writing the history of World War I on the Western Front, started by Brig.-Gen. Sir James Edmonds twenty-eight years ago. A few volumes covering certain special earlier periods are still to be issued, but these are now in proof form. It is perhaps true to say that less has been written about these final days of the war than of any other period and on that account at least this volume is of special interest.

Besides the usual account of the actual operations, on the same lines as in the other volumes of the History of the War, this book also contains three special items of interest, namely :—

(*a*) An account taken from German sources of what was happening behind the enemy front and the political events preceding the German collapse.
(*b*) Reflections on the campaign.
(*c*) Retrospect of the whole war.

The publication of this volume was delayed by the second World War and it represents the culmination of twenty-eight years most strenuous work by a very distinguished Sapper Officer. The *Manchester Guardian*, in their issue of 11th March, 1948, in a leading article entitled " Magnum Opus " gave due credit to this wonderful achievement, which is so well described in the following extract :—

" When the reader closes the last page of to-day's new offering he may reflect in awe and gratitude upon the sustained zeal of Brig.-Gen. Sir James Edmonds, who is now eighty-six years old, and for twenty-eight years has been compiling and editing the Western Front histories and has had charge of the Historical Section of the Committee of Imperial Defence and the Cabinet Office. A sapper subaltern in 1881, a Staff College contemporary of Haig and Allenby in 1895, the Deputy Engineer-in-Chief in the earlier B.E.F., Sir James undertook at the age of nearly sixty his greatest task. The second World War came to disturb the finishing touches, but the work has been done. 'The German official history of the Western Front in 1918 has not yet been published,' he remarks in his preface, 'and no official monographs on the period dealt with are available'."

C.C.P.

## THE GOOD SOLDIER

*By* Field-Marshal Earl Wavell. (Macmillan 8s. 6d.)

A BOOKSELLER sent me Field-Marshal Earl Wavell's new book *The Good Soldier*. He could not have made a better choice.

The contents are in themselves not new. They consist of previous writings and lectures. The first, chronologically, is an essay, written for a prize. The essay did not win the prize for (as the author says in a Prefatory Note) " it was turned down by the judges as too advanced and visionary for practical purposes." But it is a model of what a military essay should be. It describes war and the future of war as the author foresaw it. The style is delightful. And what the author says is good prophecy.

With this essay is printed one written in 1928 for the *Encyclopædia Britannica* on " The Development of Armies, 1870–1928." No one looks in these august volumes for light reading ; but here is something which, if not light, is at least palatable. He sounds a warning that we in Britain must heed, now that we too have conscripts : " . . . there were certain defects . . . in the Prussian system. The chief of these was the effect on the officers of the hard work and almost unvarying routine which the training of such large masses imposed. The great majority of regimental officers passed their whole military life in the same garrison town, instructing at high pressure successive batches of recruits . . . Such officers had inevitably a narrow mental outlook and tended to lose initiative . . ."

For sheer delight, let the reader turn to the two articles on " Military Genius," published in *The Times* of October, 1942. The author was then the C.-in-C. in India. Yet, rising superior to his worries, he wrote these two light essays. The first sets out the qualities of military genius and lists the generals of history who, in the author's judgment, lay claim to it. The next selects the generals, as it were, for a team. Both essays were written without notes and without reference to libraries. He deals as effectively with the exploits of the great captains who lived 2,000 years and more ago as he does with those almost of his own generation.

In a like theme, but more erudite and better known, are the three lectures on " Generals and Generalship " delivered at Trinity College, Cambridge, in 1939 and published in 1941. Here is the considered opinion of a well-read man with all the stores of scholarship at his elbow. One expects something masterly and one gets it. Yet the low-brow need not be afraid. The charm of all his writings is that Lord Wavell writes from a pinnacle of scholarship but does not look down from it with scorn upon the unlearned.

In contrast with the essays on generals and their trade comes a number of essays on the soldiery and theirs. Here the author's touch is just as sure. In his essay on " The Soldier as Citizen " he exclaims with heartfelt sincerity " A blessing on the British fighting man, on his endurance, courage, and good humour." Indeed it is no wonder that British fighting men won him such victories.

Some of his exercises are given here. They are not written, one feels, for later publication. They show how interest in training may be stimulated. They do not read well and their chief merit today lies in the light they shed of the mind of a great captain in the making.

Another group of essays deals with the infantry. The ancilliary arms (the author reminds us that *ancilla* is Latin for handmaiden) do well to ponder these essays.

An article of especial interest today is " Training for War," given as a lecture to the R.U.S.I. in 1933. In it the author stresses the superior value of training " for war " as opposed to training for any particular war. We are apt to think to-day, with all the uncertainties of atomic warfare, that unless we can foresee the pattern of the next war we cannot train for it. The same might have been said in 1933. Yet Brigadier Wavell, as he then was, put his hand on the unchanging qualities required in war and showed how he developed them in the 6th Infantry Brigade. The same qualities—discipline, physical fitness and so on—are required today.

Last, though I have not stuck to any order of chronology, merit or position in this book, come two essays on " Two Unorthodox Soldiers." Lord Wavell prefaces these with his reasons for liking unorthodox soldiers. This preface is a jewel of great price. The reader will be irresistibly drawn to the essays on Lawrence and Wingate. That Lawrence was a strange man everyone will agree. But Lord Wavell, from his proven judgment of men, says that " he was cast in heroic but very human mould, and that it was good to know him." Of Wingate, Lord Wavell writes as a C.-in-C. writes of his subordinate. He gives both praise and censure. Wingate must have been a restless being.

So let the reader look at this excellent book. He is safe in the author's hands for three or four hours. He will not put it down. On the whole, it is best for the reader to buy the book (if he can get it) for between the covers lies something of a Great Captain.

M.C.A.H.

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## THE ESSENTIALS OF MILITARY KNOWLEDGE

*By* MAJOR D. K. PALIT

(Gale and Polden, Ltd., Aldershot. Price 10s. 6d.)

A title like this cannot fail to arouse one's curiosity, if only to see how successfully the entirety of " military knowledge " has been compressed into 140 modest pages, and what " essentials " have been distilled from it. In point of fact the book is an attempt to help the student of war to develop his analytical and critical faculties, so that he may derive as much benefit as possible from his further reading. This is a worthy object, and the author—an Indian Officer—displays great enthusiasm for his task.

The book begins with a short history of tactics, so that the student shall accustom himself to the process of continual change, and be able to see any particular campaign in proper focus. Then follow a study of the evolution of strategy and an examination of each of the so-called " principles " of war. Ample suggestions are made throughout for further reading.

The final section is an account of the overrunning of Poland by the Germans in 1939, which is interesting in view of the lack of literature on this campaign, though the actual encounters were very one-sided. This is, of course, no reflection on the great courage and heroic sacrifices of the Poles.

In an appreciative foreword, Field-Marshal Sir Claude Auchinleck welcomes the book and recommends it to young officers anxious to perfect themselves in their profession.

I.S.O.P.

## TECHNICAL NOTES

### SITE INVESTIGATIONS

(*Draft B.S. Code of Practice 501* : 1947. British Standards Institution, 10s.)

This is the first Code of Practice to be issued in the Civil Engineering and Public Works Service and deals mainly with the investigation of the suitability and characteristics of sites as they affect the design and construction of civil engineering works and the security of neighbouring structures.

The scope of this Code is clearly defined as excluding site selection from the wider social and economic considerations affecting the community at large.

It also does not discuss the questions of labour, temporary housing, etc., which are considered to be outside the scope of this Code.

The objects of site investigation as an essential preliminary to the construction of all civil engineering works are :—

(*a*) To assess the general suitability of the site for the proposed works.
(*b*) To enable an adequate and economic design to be prepared.
(*c*) To foresee and provide against difficulties that may arise during construction.
(*d*) To investigate the occurrences or causes of all natural or created changes of conditions and results arising therefrom.

Based on these objects the Code collects and presents a wealth of relevant data and information, most of which is contained in numerous appendices.

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### VACUUM CONCRETE

(Paper No. 5577 by Kurt Billig, A.M.I.C.E., published in the *Journal of the Institution of Civil Engineers*, January, 1948)

It is a well established fact that concrete with a low water-content is superior in every respect to concrete of a higher water-content provided that both are of equal cement/aggregate composition and are placed under equivalent conditions. Therefore, it is generally desirable to keep the water-content as low as is practicable or economical. One method of achieving this is to use the minimum of water in mixing. The resulting concrete is very dry and has to be strongly tamped or mechanical vibrators may have to be used.

Any extra mixing water which may be added to the concrete to make it workable has a deleterious effect on most of the qualities of the concrete.

In the past, therefore, many attempts have been made to eliminate the excess water from the mix before the concrete has set and hardened. The only effective method towards this end has proved to be the pressure treatment of concrete immediately after it has been placed in the forms.

Pressure can be applied in three ways:—

(*a*) By hydraulic means used for paving slabs and building blocks.
(*b*) By using inflatable outer and inner moulds, producing a plastic deformation of the concrete as it sets, used for pipes and tubular units.
(*c*) The so-called vacuum process.

By the vacuum process, excess mixing water is removed from the concrete after it has been placed in the moulds, through the agency of suction mats connected to a vacuum pump. The suction available being approximately 12 lb. per sq. in., this being enough to secure the expansion of the excess water for all practical purposes. It also considerably reduces the cavities which have been occupied by the excess water, compacts the concrete and improves its texture.

The author describes the past history, the technology of treatment and properties of vacuum concrete, the equipment required, and the practice of vacuum treatment.

## LIGHTING

(*Abstract from annual report of Chief Inspector of Factories for the year 1946*, published January, 1948)

The outstanding feature of the year in regard to artificial lighting has been the marked increase in the installation of the standard type of tubular fluorescent units in all types of factories. Although these have been widely used in large factories, their adoption in smaller works has been particularly noticeable, possibly because owing to the large demands and the shortage of supply, the smaller firms have been able the more readily to obtain a sufficient quota for a complete installation than the larger. One Inspector reports that "fluorescent lighting is regarded by most occupiers as the answer to all lighting problems." Be that as it may, it is undoubtedly popular, and by reason of the fact that the fitting of it presents no special difficulties, the installation can readily be carried out without resort to outside skilled technicians. Unfortunately, this all too frequently results in firms failing to obtain expert advice from illuminating engineers, and consequently the installation often lacks efficiency.

## COLOUR

During 1946 the British Colour Council published a booklet entitled *Colour Schemes for the Interior Decoration of Factories and Offices* which, in addition to giving details of various schemes, set forth briefly basic principles of the use of colour and various considerations which must be taken into account in order to ensure satisfactory and pleasing results, in particular the co-ordination of colour and light.

## CONDUCTOR RAIL DE-ICING EQUIPMENT

(*The Engineer*, dated 21st November, 1947)

Conductor rail de-icing equipment is being installed over the whole of the open sections of the L.P.T.B. system. The machine consists of a metal bath containing anti-freeze liquid, which is fed by means of a rubber roller. This roller comes into contact with the carriage collector shoes of all trains passing over it and the anti-freeze liquid picked up by the shoes is then spread as a thin continuous film along the top surface of the conductor rail. This machine is operated by a small hand lever which puts it into or out of service as required according to the weather. Experiments are, however, still being made to discover a means by which the machine can be turned on or off according to the severity of the weather.

## TRACK REINFORCEMENT ON SOUTHERN RAILWAY

(*The Engineer*, dated 28th November, 1947)

On certain older sections of the main line system where the track rests on a clay-foundation, the increasing frequency and speed of modern heavy trains has made track maintenance both difficult and expensive. In open country the poor bearing qualities of clay has been effectively overcome by increasing the depth of ballast between the sleepers and the clay. However, where conditions are such that the height of the track cannot be raised the practice of " blanketing " has been adopted.

Blanketing is effected by excavating the clay for a predetermined depth and replacing it with a more suitable material. Before treating a section of track in this manner soil specialists determine, by means of borings, the depth to which excavation must be carried in order to reach a level where train loads can be supported by the introduction of the new material, usually composed of stone or granite dust and ballast.

## AUTOMATIC TRAIN CONTROL ON L.M.S. RAILWAY

(*Railway Gazette*, dated 5th December, 1947)

Automatic Train Control on the Hudd intermittent inductive system has been brought into use at 110 distant signal locations between Bow and Shoeburyness. One permanent magnet and one electromagnet fifteen yards apart are associated with every distant signal. The permanent magnet, by inductive action with a receiver on the locomotive opens a horn valve and begins a brake application. If the signal is " off " however, the electromagnet is energised which has the effect of silencing the horn and suspending brake application. The driver himself can silence the horn and retain full control of the braking provided he acknowledges a warning within three seconds of its being received. Fog-signalmen are being dispensed with on the section now equipped for the first time on a British railway with A.T.C.

## EXPERIMENTAL GAS TURBINE LOCOMOTIVE UNIT

(*Railway Gazette*, dated 5th December, 1947)

A new locomotive gas turbine unit having an output of 4,000 h.p. has been designed and constructed at Baden, Switzerland, and is now in process of development. The most interesting feature is the novel design of the high pressure stage, which incorporates a pressure exchanger.

This article, besides presenting a general description of the new unit, gives diagrams and photographs of the turbine and also the arrangement of the projected 4,000 h.p. gas turbine electric locomotive.

## BRITAIN'S FIRST MAIN-LINE DIESEL LOCOMOTIVE

(*Modern Transport*, dated 13th December, 1947)

The first main-line diesel-electric locomotive has just been completed and is now undergoing trials in competition with the latest types of steam locomotives.

This locomotive is powered by a 16 cylinder, 1,600 h.p., " English Electric " diesel engine which has been designed to work alone or, when coupled with a second unit, to form a 3,200 h.p. locomotive capable of working the heaviest long distance expresses and of attaining a maximum speed in suitable conditions of approximately 100 m.p.h. The new locomotive has been numbered 10,000, and 10,001 is now under construction.