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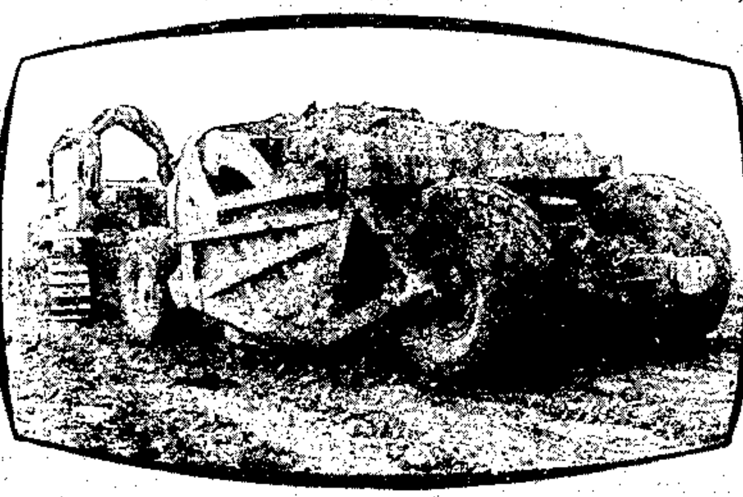

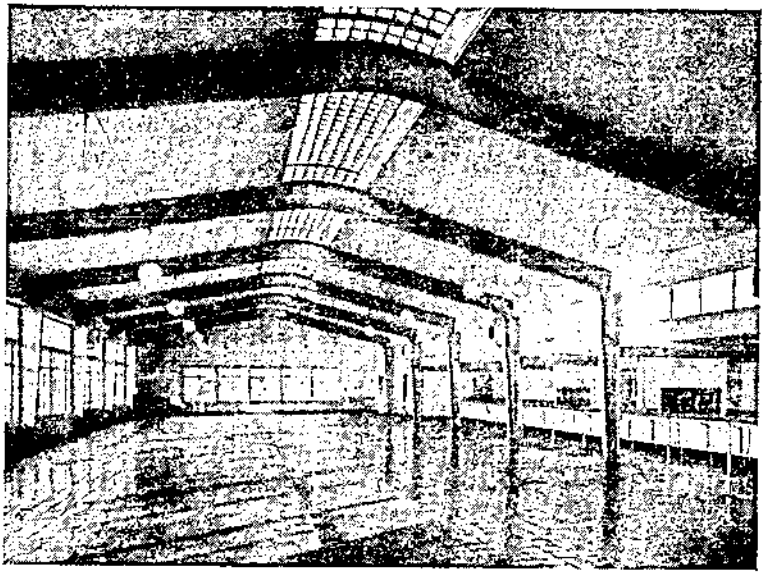

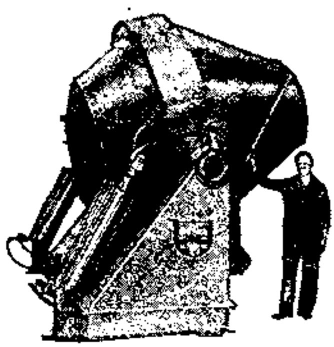

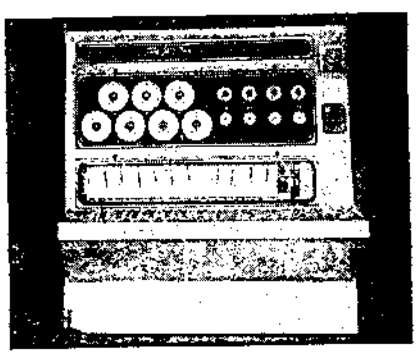

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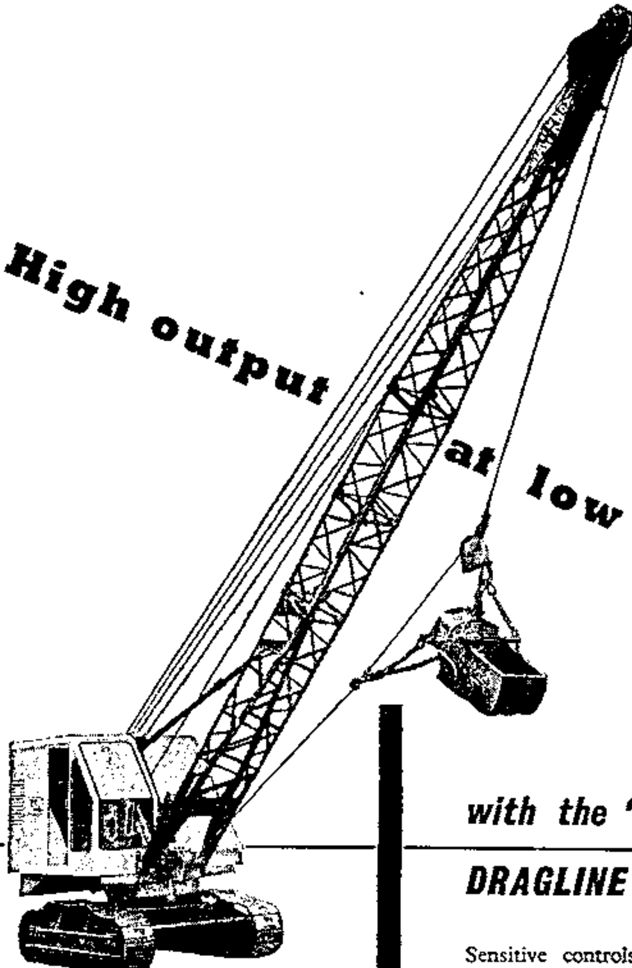

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Photo 1.—The Dropping Zone. Parachutists landing among the gliders, who had landed twenty minutes earlier.

Photo 2.—Unloading Transport from Gliders. These two gliders had collided on the crowded landing zone, but their contents were unharmed.

The Battle Of Arnhem Bridge 1 , 2

THE BATTLE OF ARNHEM BRIDGE

By Major E. M. Mackay, M.B.E., R.E.

Note.—This article was originally printed in *Blackwood's Magazine* for October, 1945. This year being the tenth anniversary of the Battle of Arnhem it is reproduced by permission of Blackwoods. The unit concerned in this story was, of course, the 1st Parachute Squadron, R.E.

Sunday

AFTER many false starts during the early summer we assembled at the aerodrome on Sunday, 17th September, knowing that at last we were going to get to grips with the enemy. The aircraft were already loaded with their containers and parachutes. The men were primed and ready to go, though somewhat cynical from many previous disappointments. We all knew the plan, its object, and what divisions were taking part, and understood that opposition was expected to be light.

At 11.15 I gave the order to fit parachutes and emplane. We were so heavily laden that we had to be helped into the aircraft ; I myself weighed 22 stone and was going to jump with a folding bicycle. At 11.30 the long line of planes, three abreast and nose to tail, began to move round the perimeter track, to form up in a solid block on the main runway. On a signal from the commander the whole mass surged forward, and we were airborne in a few seconds.

At 1.30 p.m. we crossed the Dutch coast. I ordered steel helmets to be put on, and looked eagerly down for some signs of the German retreat. We saw a glider or two down in the sea, with rescue launches fussing round them, but no Germans. We were now over the flooded areas, where little towns and villages stood with the water up to their first storeys. Our fighter escort of Mustangs, Spitfires, Thunderbolts were flashing past in pairs at nought feet. High up we could see formations of more fighters.

At 1.50 we turned north with twenty minutes to go. We could see above us the returning Dakotas, which had just dropped the Americans, flying in stately formation. Still there was no flak. We crossed the Maas near Nimjegen where the bridge remained intact. All the boys were now standing up. I grasped my bicycle firmly, looking out of the door, with one eye on the lights beside my head. The red light was due to go on four minutes before the jump. I saw some light flak positions firing between the two rivers, and heard it crackling as it passed. Suddenly there was a loud crack with a bright light just beside my face, and where the lights had been was now only a large hole. This deprived me of my communication with the pilot, who could not give me the signal to jump. The containers under the plane were to be jettisoned just before I jumped, and a danger lay in the possibility of my jumping right into them. The engines slowed down, and the air began to make that peculiar hissing noise that occurs when a Dakota is preparing for a jump. I leant out of the door, carefully watching the other planes so that I could judge my jump ; but when the time came it caught me unawares and I went out a bundle of arms and legs.

My parachute opened with a jerk and I found I was drifting backwards. I felt dog-tired, and was so heavily loaded down with equipment I hadn't the strength to make a turn. I set my teeth for a back landing, which left me breathless owing to my high rate of descent.

The sky was full of parachutes, with here and there an odd fighter flashing by. Away to the north a large fire was burning and some bombs exploding. I could see no sign of my stick, and moved over to where a number of R.E. containers were lying. As members of the squadron appeared I directed them to their containers, and after about half an hour eight members of my troop had collected, and we moved off to the forming-up point, where shortly the rest came in.

There was some desultory firing going on and we took a few prisoners. At 3.30 p.m. the jeeps arrived from the gliders and the squadron moved off to the tune of " Tiger Rag " from a portable wireless. We were eight miles from Arnhem bridge. Two battalions were to make a dash for it along different routes and had detachments of the squadron with each. My troop was to move in the wake of the southerly assault battalion. I had an independent rôle to do certain specific tasks, but could be called upon by the Brigadier in an emergency.

The C.O. was soon sent for, and I took charge of the remnants of the squadron, about eighty men. We moved off at our best pace with as much equipment as we could carry. There were thick woods on either side, and a good deal of firing seemed to be going on in them. I had orders to go straight to the bridge, so we moved steadily down the road and did not attempt to join in. Soon the noise of battle was all around ; the Germans were evidently wide awake and attempting to stop the advance.

After about an hour the Dutch began to appear along the route. They seemed oblivious of the fire, and lined the road, cheering and waving orange flags. This was all very nice, but it gave our positions away. However, we pressed on, and they ran alongside with apples, pears, and tomatoes. Some even brought water, of which we were badly in need, for we had been without a drink for eight hours. We ploughed steadily on ; I would allow no halts ; the position got more and more sticky.

About 6.30 we reached the outskirts of Arnhem, only to see the railway bridge blown up in our faces : the leading battalion had been held up at the station. It was evident that they were open to attack from their northern flank ; so I was ordered to hold that flank while the opposition in front was overcome. I managed to scrounge fifty R.A.S.C. with an officer ; this, together with my eighty R.E., gave me the equivalent of an infantry company. We moved north into the town and took up positions on three cross-roads.

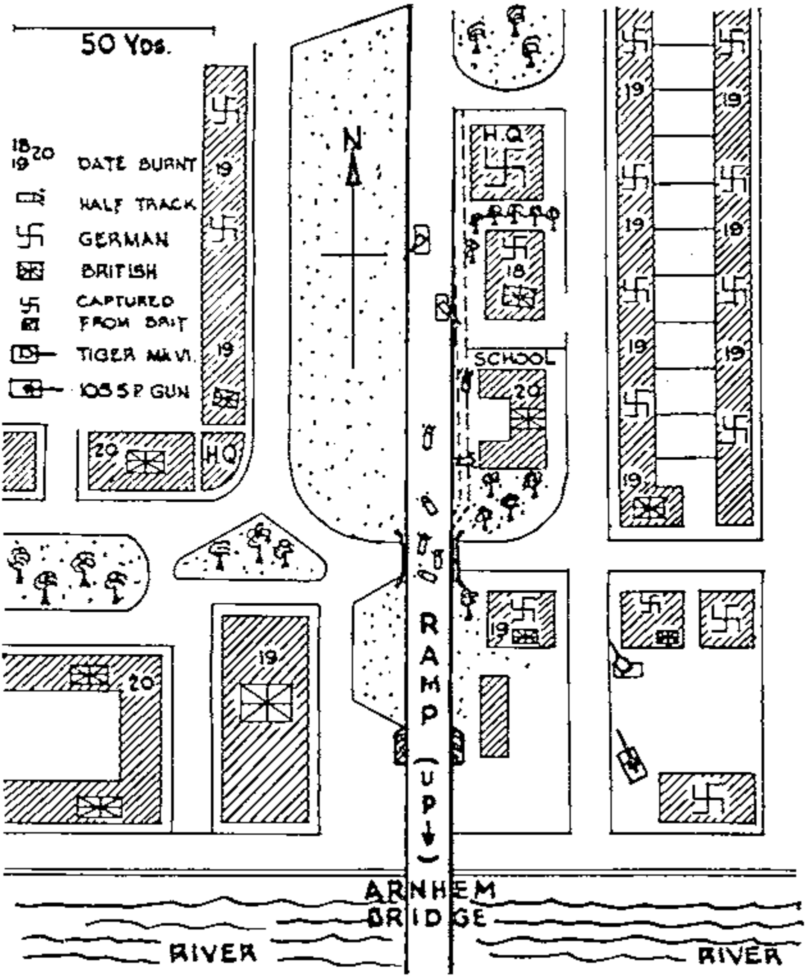
In front of us we could hear a fierce battle raging. Evidently the northern assault battalion had run into bad trouble ; for the enemy were now between us and the rest of the division. But I saw no cause for anxiety, and we held this position till about 8 p.m., by which time it was quite dark. Word came to move on into the town. I disengaged my force, covering them with my own troop, which became the rearguard. In the darkness we lost touch and found ourselves on our own, half a mile in rear of the rest of the force.

We pressed on into the town. It was very quiet, but some distance ahead we could hear firing, and some houses were burning. All around us there seemed to be surreptitious movement. The men were feeling the strain after their forced march without food for fourteen hours, and we were pulling trolleys loaded with explosive, occasionally up steep hills. The pace was cracking ; but we dared not stop, for we could hear the enemy moving along parallel streets.

By nine o'clock we reached a small square on the water-front. The enemy came down a side street and caught us on the hop, and one explosives trolley went up in flames. After a sharp scrap we disengaged and pushed on. We came to the pontoon bridge, which was guarded by a Vickers machine-gun and crew. The enemy immediately attacked across it from the south, but this attack was repelled with heavy casualties to the enemy ; our only casualty was a bottle of rum. We were now within 600 yards of the main Arnhem bridge, where a fierce battle was raging.

I determined to push on. The enemy had now infiltrated between my small force (thirty-five) and the force at the bridge. They were in a square lying across our path. My first four attempts to cross this death-trap failed, but we managed to drive them up a side street. They set up two machine-guns in ground-floor windows covering the square. It was imperative to reach the bridge, so I lined up my troop, complete with trolleys, on the edge of the square. When all were ready, we ran across the forty yards of open ground. The risk was justified, for there were no casualties.

We pressed on and reached the bridge a few minutes later. Here the situation was not good. The force consisted of the two remaining companies of the assault battalion, about a hundred of my squadron including my force, some R.A.S.C., and most of Brigade H.Q. staff, about 400 men in all. The enemy were still on the bridge holding a pill-box, supported by an armoured car ; the whole area was under fire from 88-mm. guns on the far bank.



Shortly after we arrived an assault went in supported by some of our R.E. with flame-throwers. There was a bloody battle, with heavy casualties on both sides. Eventually the bridge was captured. Three ammunition trucks caught fire and started exploding. The whole area became as light as day. While this was going on my men had half an hour's well-deserved rest. I contacted the senior officer, and he indicated some positions just to the east of the bridge.

The main Arnhem bridge was high above the river. Leading up to it was a long ramp, under which were two tunnels, and through them lateral roads passed. On the east side of the ramp were four houses directly alongside. Of these, the three southernmost were the most important ; the fourth was blanketed by trees. Whoever held these three houses held the bridge ; the centre one was a school and on the corner of a cross-roads. This was an extremely strong position, virtually the key to the whole layout. I was given the task of defending the school and the house immediately north of it.

I managed to accumulate fifty R.E., my own troop, and half of another. We moved with circumspection through the tunnel, for no one had been through to the east side before. I went with eighteen men into the northernmost of my two buildings ; the rest of my force I put in the school. It was a large house consisting of offices ; trees and bushes grew right up to the northern face, giving no field of fire in that direction. I did not like it, but set about breaking all the glass from the windows and fortifying it.

Ten minutes later we were heavily attacked. (I learnt later that the next house, fifteen yards away, was a German Company H.Q.). The enemy crept through the bushes and right up to us before we were aware of them. They threw grenades through the ground- and first-floor windows. Almost immediately they got a foothold in the basement, but determined hand-to-hand fighting with fists, boots, rifle-butts, and bayonets dislodged them.

The situation deteriorated rapidly. They brought up a machine-gun and poked it through a window, spraying everyone in the room. Fortunately I was beside the window, where I shot the gunner and reversed the gun on the mob outside. Grenades were now coming in at all the windows, and the din was terrific. It was apparent that if we stayed any longer we should all become casualties—nearly half the force was already wounded. To evacuate our wounded we had to clear the garden first. Accordingly I took my sergeant and six men into the garden, where we mixed it in the bushes. The enemy had no stomach for cold steel, and retired to the house next door, where we followed him up with grenades. A taste of his own medicine. We kept up a hot fire while my corporal got the wounded over the high wall that separated us from the school, and then we joined the rest of the force in the school. We had seven wounded, though few of them seriously. Myself, I had one or two minor shrapnel wounds and a cut in my head, where a bullet had gone through my helmet, more messy than painful. The time was about midnight. So ended the first day.

Monday

We still had six hours to go till dawn. I made a hurried reconnaissance of the school. It had a basement, two floors and an attic, and I decided to fight the battle from the first floor, merely holding the basement and ground floor, and to observe from the attic. I had fifty men (seven wounded), one other lieutenant, six Bren guns, plenty of ammunition and grenades, and a certain amount of explosive ; no anti-tank weapons, very little food, and only the water in our water bottles ; no medical supplies except morphia and field dressings.

There was a breathing space of an hour before the next attacks were made: two were driven off before dawn. During lulls we went out and collected one or two wounded paratroops from the area.

Dawn was heralded by a hail of fire from the house we had been driven out of a few hours previously. As it was only twenty yards away, our positions on the northern face of the school became untenable for anything but observation. As soon as it was fully light, we could see the exact positions held by the enemy next door. They very foolishly remained in them, and it was easy to form a plan to eliminate them. One machine-gun was fired by remote control from one end of our northern face. It drew all the fire, while from the other end we opened up with two Bren guns, and killed all the machine-gun crews. More of the enemy attempted to recover the guns, and were immediately eliminated. The time was now 8 a.m.

Meanwhile a battle seemed to be developing round our southern face. The Germans were putting in a strong attack on the house sixty yards south of us, and against a small force holding the other corner of the cross-roads on the opposite side of the street. A great deal of firing was going on and tracers were flashing all around. Someone was firing a light ack-ack gun straight down the street. It was all very confusing. No one seemed to know who was who. We joined in with our southern machine-guns as best we could. The battle seemed to be reaching a climax about 9.30 when a cry came from one of the west rooms to say an armoured car had just gone past the window.

I rushed over and was in time to see a second go by. The ramp was on a level with our first floor, with its edge about twelve yards away. We could do nothing against these armoured cars, having no anti-tank weapons. However, after five had gone by, some armoured half-tracks tried to sneak through. These have no roof on them and so were dead meat. The first went by with a rush, but we managed to land a grenade in it. The second came on with its machine-guns blazing, and a man beside me was killed before we could stop it by killing the driver and co-driver. The crew of six tried to get out and were shot one by one, lying round the half-track as it stood there in the middle of the road.

This caused the remaining half-tracks to stop just out of view, and gave me a breathing-space to organize a system for their elimination. Ten minutes later two came on together, firing everything they had, in an attempt to force the passage. As they passed the one that was already knocked out, we shot the driver and co-driver of the leading half-track. The driver must have been only wounded, as he promptly put it in reverse, and collided with the one behind. They got inextricably entangled, and we poured a hail of fire into the milling mass, whereupon one went on fire.

As the crew tried to get out of both, they were promptly killed. The score was beginning to mount. Another tried to take advantage of the billowing smoke to get through. It was similarly dealt with and there were no survivors. There appeared to be a lull, when suddenly I heard a clanking just below the window. On looking out, I saw a half-track just below me. It was about five feet away and I looked straight into its commander's face. I don't know who was the more surprised. It must have climbed down the side of the ramp and was moving down a little path, nine feet wide, between it and the school.

His reaction was quicker than mine ; for with a dirty big grin he loosed off three shots with his Luger. The only shot that hit me smashed my binoculars, which were hanging round my neck. The boys immediately rallied round, and he and his men were all dead meat in a few seconds. The half-track crashed into the northern wing of the school.

There was a further lull of about half an hour, when another half-track came down the ramp at full speed. The driver was promptly killed. The vehicle swung right, rushed down the side of the ramp, crashed head-on into the southern wing, just below us, where the rest of the crew were dispatched. While this was going on, another nosed out from behind the burning trio on the road. The same system was employed, and another eight Germans joined the growing pile. We were doing well, and our casualties were comparatively light.

It was nearing midday, and although there was a certain amount of clanking in the distance, no further attempt was made to force a crossing from the south. In any case the bridge was now blocked by burning vehicles. This lull was too good to last. Ten minutes later, with a sighing sound, fifteen mortar bombs landed on and around us. I could hear fire orders being given in English from the other side of the ramp, and realized we were being mortared by our own side. Leaning out of the nearest window, I gave vent to some fruity language at the top of my voice, the authenticity of which could not be doubted. The mortaring stopped.

To clinch matters, we let loose our old African war-cry of " Whoa Mahomet." This had an immediate effect, and was taken up by all the scattered points and houses round the bridge. The firing died down, and soon the air was ringing with the sound. Morale leapt up. Throughout the succeeding days this was the only means of telling which buildings were being held. It was one thing the Germans, with all their cleverness, could not imitate.

In this lull, lasting an hour, we reorganized our defence for the most economical use of men, reloaded used magazines, and took stock of the ammunition. I went down to the basement, where I set up a hospital for the wounded. In charge I put a Sapper, who had once been on a first-aid course. I gave him explicit instructions on the treatment for the various cases. The other end of the basement, under the stairs, became the mortuary.

The ration situation was critical. None of us had had anything to eat since six o'clock the previous morning. We had enough to last us a day with care, and had managed to fill a bath before the water had been cut off. The two signallers repaired the set, and I got on to the Colonel. I told him we were quite happy and could hold out till the following dawn. He said this would not be necessary as help was very near. The Second Army was only five miles south of us, and the rest of our division was battling its way into the town one and a half miles to the west. This news was passed on to the men, which pleased them.

Having done my tour of the defences, I went upstairs and had a biscuit and two boiled sweets. Immediately heavy fire was brought to bear on our eastern face from across the street. During the lull the Germans had infiltrated into the houses opposite, and one of the machine-guns they had set up was firing straight down our stairs, our only means of communication between floors. Simultaneously the battle broke out in earnest on the cross-roads forty yards south of us.

The southern two machine-guns, plus a few snipers, had their instructions and joined in joyfully. The east face was a more ticklish problem. I decided to use the tactics that had been so successful on the north face in the early morning. Accordingly, one Bren was fired by remote control, while the others eliminated the posts as they fired. After three and a half hours of this we had succeeded in clearing the houses opposite. Nothing daunted, a fresh lot of Germans came out of their H.Q. sixty yards north of us and attempted to set up a mortar to fire straight at us. We let them come. As soon as they were within thirty yards, they put it down and started to erect it. They were closely bunched, and one burst was sufficient. Some more came out to rescue the mortar, and were likewise eliminated ; after this they desisted.

Time was getting on. The six o'clock news said everything was going according to plan. We could hear heavy gun-fire away to the south, but still no relief. We started making preparations for the night. I had not now sufficient men to man all the ground-floor rooms. These were barricaded off and loopholes knocked into them from the hall, where I kept a small garrison. Two rooms only were kept open. The half-track resting against the south wing was evidently a ration truck, and was full of food and cigars. This, together with all the knocked-out machine-guns, would prove a useful addition to the defence. As soon as it was dark enough, I determined to take out a patrol and recover all this booty.

When dusk fell, the Germans opened up a furious fire from the next house to frustrate this plan. They followed this up by projecting small mortar bombs into all the northern rooms, which made them temporarily untenable. Under cover of this a flame-thrower was brought up and set the nearest half-track on fire. The crew of the flame-thrower were promptly killed, but the damage was done. Almost immediately the second half-track was set alight by incendiary bullets.

Bang went our rations, but, worse still, both were burning merrily against the west face of the house. All attempts to put out these fires were doomed from the start. Every time we went out to deal with them, silhouetted against the flames in the darkness, we drew the fire of every machine-gun that could see us. Meanwhile, the walls were becoming hotter and hotter. Eventually, two bright sparks crawled out and put a charge of explosive under each and blew them to pieces. The explosion shook us, but saved us. All danger was past by nine o'clock.

The enemy promptly set the house next door on fire in another attempt to burn us out. By 9.30 it was going well. A high wind sprang up and burning fragments were blown on to our wooden roof, which soon began to smoulder. The fire-fighting party moved up to the roof with the A.R.P. appliances supplied by the Dutch Government. The whole area was as bright as day, and they immediately came under harassing machine-gun and sniper fire.

Covering fire was given as much as possible from the floor below. Parties were changed frequently on account of the intense heat and tiring nature of the work. After three hours' fire-fighting, everyone was exhausted, but the danger was past. We had now been fighting almost continuously for thirty-four hours ; no one had had any sleep for forty-three hours and very little food and water. There were two dead and seventeen wounded out of fifty. So ended the second day.

Tuesday

At 1 a.m., Tuesday, the fire next door died down sufficiently for the enemy to launch an attack. They projected small bombs into all the northern and eastern rooms, and pressed on with great determination. This attack was successfully driven off, though I was forced to close my last two outer rooms on the ground floor, no longer having sufficient men to man them.

There was a lull for half an hour. During this period we bound up our feet with strips of rag to make our movements through the house silent. The stone floors were covered with glass, plaster and fragments of metal, and were slippery with blood, especially the stairs. So every step crunched and was plainly audible for fifty yards.

Suddenly there was an appalling explosion in the south-west corner room. I rushed over with my batman. It seemed to be full of debris and someone was groaning in a corner. There was a blinding flash, and the next thing I remember was someone shaking me and slapping my face. I had been blown across the room, and was half buried under a pile of fallen brickwork. The whole south-west corner of the school, plus part of the roof, had been blown away. Everyone had become a casualty, and, by the time I was brought round, had been carried below, including my batman, who was blinded.

I found out later that the weapon that wrought this havoc was an anti-tank projector, which threw a 20-lb. bomb. The enemy failed to follow up his advantage, many of the boys being dazed by the explosions. We were given a breathing-space, but not for long.

Twenty minutes later, on looking out of a window, I was amazed to see a dozen Germans below me, camly setting up a machine-gun and a mortar. They were talking and were evidently under the impression that all resistance in the house had ceased. A hurried reconnaissance revealed that we were entirely surrounded by about sixty Germans, at the range of some ten feet, who were unaware of our existence.

It seemed too good to be true. All the boys were tee'd up at their windows, grenades ready with the pins out. On a signal, grenades were dropped on the heads below. This was followed up instantly by all our machine-guns and sub-machine-guns (six Brens and fourteen Stens) firing at maximum rate. The boys, disdaining cover, stood up on the window-sills, firing machine-guns from the hip. The night dissolved in sound, the din was hideous, the heavy crash of the Brens mixed with the high-pitched rattle of the Stens, the cries of wounded men, punctuated by the sharp explosions of grenades, and swelling above it all the triumphant war-cry, " Whoa Mahomet."

It was all over in a matter of minutes, leaving a carpet of field-grey round the house, together with a few machine-guns and mortars. It was about 3 a.m., and it looked as if we'd have a quiet time till morning. I went down and dealt with the wounded, while ammunition was redistributed upstairs. I had collected some additional bits of metal during the earlier attacks of the night. The piece that was really painful was in my foot, as it impeded my movement and pinned my boot to my foot. My acting medical orderly tried to get it out, but failed.

I was only really worried about two of the wounded. One was obviously dying with fifteen bullets through the chest ; and the other, shot through the back of the head, was looking a bit grey, and snoring. There was another, who was a little rocky, with one bullet through the stomach and three through the arm. The stomach wound was all right ; nothing vital was hit, and I shoved a plug in it. Most of the wounded were suffering from shock and fatigue. I had plenty of morphia and kept them all well doped. I went upstairs about 2 a.m. and checked the defences for the expected dawn attack.

The wireless was working, and I got on to the Colonel, gave in our strength return, said we were all happy and holding our own. Dawn was heralded by an intense mortar and machine-gun barrage in the neighbourhood of the cross-roads. This was followed by a half-hearted infantry attack, which was easily routed. I moved round to

Photo 3.—The Approach March. Sappers marching in, pushing trolleys loaded with explosives and tools.

Photo 4.—The Approach March. Repelling an attack on the road to Arnhem.

Photo 5.—Fighting in the Woods. A typical scene after an enemy attack where some armour had intercepted one of the columns fighting its way into Arnhem.

Photo 6.—In Arnhem. Street fighting in the town itself.

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the northern face to observe that end, when there came a cry from the south, "We're all right ; there's a couple of Churchills outside."

I hurried over to find myself looking down at a couple of German Mark III tanks. I held a short course in tank recognition immediately. These two tanks concentrated on the house to the south of us. As soon as the infantry appeared to support them, we joined in and eliminated them. Whereupon some of the fury of the tanks was turned on us, and the leading tank started pumping shells through our southern face. We could do nothing about this, so moved out of the room till it finished.

When the German infantry appeared in support of the tanks, we picked them off with rifle-fire. This went on for five hours, at the end of which time the enemy managed to capture the house south of us, in spite of all our efforts. There were sounds of intense fighting all round the bridge area. The *Luftwaffe* was now taking a hand attempting to bomb individual houses. We were doing well at the other end of the school. The enemy came out of their H.Q. with a white flag and asked to surrender. We could take no prisoners as we had no food or water, so we told them to get back there and fight it out. This they did. Soon they tried to make a break, and were eliminated.

It was now midday, and to the south things did not look too bright. The tanks were coming up in relays from the water-front. The next-door house to the south was gone, as was the one on the opposite side of the cross-roads. The only other position, besides ourselves, on the east side of the ramp was holding out with difficulty. I contacted the Colonel on the wireless and told him I could not hold out another night if I was attacked on the same scale as on the night before. He said he could not help me, but I was to hold on at all costs. The Second Army was still five miles away and we could hear the heavy guns firing steadily. The B.B.C. said everything was going according to plan and that relief was imminent.

The tanks at the cross-roads moved back to the water front, presumably for lunch. Meanwhile we came under a heavy mortar. One delayed-action bomb came through the roof and burst in my command post, killing one and wounding all the others. At that moment I was looking out of the east face, for something suspicious was happening in the houses opposite. Ten minutes later a ripple of fire broke from the other side of the street. The Germans had infiltrated again into their positions of yesterday afternoon. They seemed to be much stronger, and poured a hail of fire into all the eastern windows, stopping all movement up and down the stairs. I tried the same old gag as yesterday and eliminated the posts one by one. By four o'clock we had cleared them out of all their positions in that row.

Meanwhile the tanks had had their lunch, and reappeared at the cross-roads, and we had a repetition of the morning's performance.

The south of my school that was still standing was beginning to get a bit battered from the constant shelling and penetration of armour-piercing machine-gun bullets. However, we were still killing a lot of Germans. A favourite game of my sergeant's was to let them get into the house south of us, as we had all the windows taped, and then eliminate them either in the house or as they tried to escape from this death trap.

At 3.30 an amazing incident occurred. The *Luftwaffe* had been increasingly active all day. A Focke-Wulf 190 came over the bridge from the south and attempted to bomb the school. The bomb failed to explode, hit the road and bounced. The F.W. 190 took evasive action from our machine-gun fire, hit a church steeple, which tore off its port wing, and crashed in a square 400 yards away. Great joy all round.

At about 4.30 the tanks withdrew from the cross-roads. The reason was soon obvious. German incendiary parties had fired the house south of us, both ends of the houses opposite on both east and west sides. Within an hour the whole area of the bridge appeared to be blazing. The small force that had been holding out so gallantly on the opposite side of the street was forced gradually nearer us by the mounting flames, and looked like being burnt out completely.

I turned on the six o'clock news and learnt with amazement that we had been relieved. The sound of guns to the south was not getting any nearer. It looked like being a sticky night. During the afternoon I had kept the wounded making improvised bombs out of our stock of explosive and anything we could lay our hands on. I did not think we could last the night, for our numbers and ammunition were getting low. About seven o'clock the sound of two heavy engines, coming up the ramp from the north, was heard.

Into view rolled two Tiger tanks. These 62-ton monsters, with their huge 88-mm. guns, would finish us in a matter of minutes. They covered each other up the ramp, shelling the west side of the street. When the leader got within thirty yards of the school it turned its enormous gun deliberately on us. There were two appalling explosions, and the whole north-west corner of the school was blown away. I promptly sent the survivors on the first floor down to the basement. I moved up to the attic myself to observe, in case they pulled a fast one by launching an infantry attack, supported by these Tigers.

I noticed the German infantry clearing the row of houses to the west under cover of the tanks, while the nearest one kept us occupied. The Tiger now changed to armour-piercing shot and let go two rounds. These shots went right through the first floor under my feet. They knocked a four-foot hole through eight walls and came out the other side of the house. A little more of this and the school would be reduced to a pile of rubble. The concussion was terrible and the whole building shook.

By now it was fairly dark, although the whole area was lit by the blazing houses. A pall of smoke hung over us, which reflected in a ruddy light. The two Tigers evidently did not fancy their chances in this uncertain light, and moved off northwards. Not a moment too soon. Two more shots would have finished us, and I was debating the possibility of taking a party out and blowing them up with some of our home-made bombs.

We remanned our positions on the first floor. Thanks to the Tiger we now had plenty of loopholes, and as long as the houses kept burning we could hold our own. The men were beginning to show signs of fatigue, and I issued Benzedrine. This had a peculiar effect on some, giving them double vision ; it made others see things that were non-existent. We stood by all night, but were not attacked. There were one or two skirmishes as German patrols tried to get by. These were suitably dealt with. No one could afford to go to sleep as we were few in numbers. The casualties were now four killed and twenty-seven wounded out of fifty. So ended the third day.

Wednesday

By morning I had to issue more Benzedrine to face the dawn attack. No one had now had any sleep for seventy-two hours. The water had given out twelve hours ago and the food twenty-four hours ago. As expected, with dawn the tanks came rolling up from the water front, with infantry supporting We were now alone on the east of the bridge. Every house was burnt down, with the exception of the one on the opposite corner of the cross-roads, which was in German hands.

We drove off three attacks in two hours. The school was now like a sieve. Wherever you looked you could see daylight. The walls were no longer bullet-proof, rubble was piled high on the floors, laths hung down from the ceilings, a fine white dust of plaster covered everything. Splattered everywhere was blood : it lay in pools in the rooms, it covered the smocks of the defenders, and ran in small rivulets down the stairs. The men themselves were the grimmest sight of all : eyes red-rimmed for want of sleep, their faces blackened by fire-fighting, wore three days' growth of beard. Many of them had minor wounds, and their clothes were cut away to expose a roughly fixed, blood-soaked field-dressing. They were huddled in twos and threes, each little group manning positions that required twice their number. The only clean things in the school were the weapons. These shone brightly in the morning sun, with their gleaming clips of ammunition beside them. Looking at these men I realized I should never have to give the order " These positions will be held to the last round and the last man." They were conscious of their superiority. Around them lay four times their number of enemy dead.

By ten o'clock the enemy gave up their attempts to take the school by storm. They concentrated on the force now under the arches of the bridge, about eighty men, nearly all that remained of the original 400. These were eliminated by about two o'clock, when our last cry of "Whoa Mahomet" was answered by silence. We were now the last organized position holding out near the bridge. It was a matter of time before we succumbed ; for we were heavily outnumbered, and there was a great weight of armour and self-propelled artillery against us.

At three o'clock I noticed considerable activity between the cross-roads and the water-front. A Tiger tank appeared, followed by a very large self-propelled gun (I found out later it was a 105 mm.). They opened fire at 80 yards range. The first salvo killed Corporal Joe Simpson, a gallant veteran of many battles, wounded three others, and blew away the rest of the southern face. The remainder had to retire to the cellar. The house went on fire in four places, as salvo after salvo crashed into it. Very soon our stock of explosive in the top floor caught fire and blew up. The whole of the top of the school was blown off and the house was blazing like a torch. In the cellar I had fourteen able-bodied men, thirty-one wounded, five dead. The house was beginning to collapse and the heat was intense. I considered it necessary to evacuate.

Accordingly I ordered Lieutenant "Stiffy" Simpson to lead the break-out northwards with our six Bren guns. With the remaining eight men, six became stretcher-bearers, and two with me acted as rear-guard. "Stiffy" got into the burnt-out ruins of the house to our north and successfully covered me as I organized the evacuation of the wounded. We moved all the wounded safely into the garden of "Stiffy's" house. I told him to press on northwards as it was impossible to go in any other direction. There were tanks roaming up and down the roads fifteen yards on either side of us, and to the south the remains of the school were still exploding from time to time.

As "Stiffy" tried to cross the wall leading to the next house he was wounded. We now came under intense machine-gun and mortar fire from the houses immediately to the north and east of us. Very quickly another seven were wounded and one of the wounded was killed. It was obvious that they would be massacred if we held out any longer. Accordingly I ordered "Stiffy" to surrender with the wounded, and with the remaining six men I doubled back on our tracks, each of us carrying a machine-gun of some sort. I now determined to head east into the next two blocks of burnt-out houses.

We lined up on the edge of the road. On the word "go" we ran across the road and dived head-first into the burnt-out houses on the other side. As we did this there was a tank coming up the road from the south. It opened fire at ten yards range, but did not allow for deflection, and we passed through unscathed. The houses were extremely hot still from the fire the day before, so we moved swiftly through into the gardens beyond. We pressed on, fearing pursuit, and burst out from the next row of burnt-out houses into the road beyond.

We came face to face with approximately fifty Germans, standing beside two yellow Mark III tanks. They looked terrified at our appearance. We stood in a line with our six machine-guns, firing from the hip. We pressed the triggers continuously till the ammunition ran out, about three seconds. It was a pleasant sound. We had one killed and one wounded. I retired with the remaining four back into the gardens. We were now completely unarmed. We split up, one per garden. I told them to rendezvous with me at nightfall and we would try and contact our main forces. I was still confident that the Second Army would be up to us by dark, and we'd get some of our own back. I was furious at having lost practically my whole troop, which I had taken two years to train.

I lay down in a bush, face downwards. I felt exhausted and determined to try and get some sleep. First of all I removed my detachable pips and destroyed my identity card. Ten minutes later I heard German voices approaching. It was a party of seven under a N.C.O., evidently beating the gardens to pick us up. They came up to me and I simulated death. The N.C.O. gave me a kick in the ribs, which I received as if I were a newly dead corpse. They were evidently not satisfied, and a discussion arose. Suddenly a private ran a bayonet into me, which came to rest with a jar against my pelvis. When he withdrew it, the most painful part, I got to my feet. The time was 4.30.

They were evidently still very frightened of us and I was forced to walk with my hands clasped on the top of my head. I was led past the place where we had had our last battle a few minutes earlier. I was pleased to see several still, grey forms, and two more dying noisily in the gutter. There seemed to be masses of Germans everywhere, with tanks and self-propelled guns at every corner. I was given a preliminary searching, but managed to retain my map of that part of Europe. My flask was taken from me, but I complained to an officer and got it back. Meanwhile a few more of my boys were rounded up and we were all marched off to the S.S. headquarters.

Here I met other prisoners from the party under the bridge and some of my own walking wounded. I was the only officer present, so I warned them all it was their duty to escape. Prisoners here were stripped and thoroughly searched. I could not afford to undergo this, and managed to join the party that had already been searched. Here I proceeded to remove my tie and the pips from my battle-dress. We asked for food and water, and were given one jug of water between twenty-four of us. It was interesting to watch how the Germans ran a divisional headquarters. I studied the officers and men, and found out their regiments and equipment for future reference. They did not dare move us in daylight in case the trucks were spotted by our aircraft. Towards dusk we were marched out to two trucks.

An English-speaking officer came up and tried to gain our confidence and extract information ; but he only got back-answers. He gave it up and we were piled on one truck. Immediately two sentries tried to get on too, but we all crowded down to the back and pushed them off. This went on for some time, till eventually we compromised and allowed one sentry on. I sat on the tailboard opposite him, with two of my men between us. It was now quiet and the truck moved off down the main road to Germany, only sixteen miles away.

Surreptitiously I got both of my legs over the tailboard. Six miles later my opportunity came. The truck slowed for a bend, my two men lurched into the sentry and smothered his rifle. I jumped and rolled over twice. I had chosen a bad place for my attempt, for I landed within three feet of a sentry outside a guard-room. He gave a yell as I dived for him. I got him down, and had very nearly knocked him senseless when his pals arrived. There was a battle-royal ; I was eventually overpowered and thrown on the truck, which had stopped at the first shout. I was too dazed to make another attempt.

The truck stopped four miles farther on in a small Dutch village. We were all piled into a very small room in an inn. There was no room to lie down. We all had to sit up on the floor. We were provided each with half a pint of water, which was a blessing. I got my back to a wall and tried to make myself comfortable. Three of my wounds—my foot which had gone septic, the bayonet wound, and a head wound—were now troubling me. However, I had no difficulty in going to sleep, as I had not slept for ninety hours. I awoke some six hours later immeasurably refreshed. It was Thursday morning.

Thursday

We were let out into a courtyard, where more water was provided. Two of us had steel helmets, which we used as bowls. Among all the rest of us we managed to raise one complete shaving set. We all had a wash and shave and I attended to the wounded with us. About nine o'clock some Dutch produced a basket of apples. There were enough for two each. Our first food for two and a half days.

At ten o'clock we once again piled on our truck and were driven off down the main road to Germany. Again I managed to get on the tailboard. There were two sentries with us now. It was broad daylight and impossible to make an attempt to escape. However, I studied the route, the number of troops, and the defences on the frontier, which we soon crossed. About midday we drove through a fair-sized German town. We stopped inside a prisoner-of-war transit camp and unloaded from the truck.

The transit camp was situated in large grounds. It was a fair-sized **L**-shaped building. Across the two arms of the **L** was a high barbed-wired stockade. The top of the fence bent inwards, and where it joined the building it was continued up to the roof with additional wire obstacles facing inwards. Outside the fence was a guard-room made with openwork sides, so that the whole guard could view the fence from inside it. There were two sentries pacing up and down the fence, with a couple of searchlights nicely situated to help them at night. The building itself was of extremely stout construction. The long side consisted of one large room in which about a hundred prisoners could be housed, with bunks enough for fifty. The roof was very high, and supporting it were four wooden pillars with barbed wire wound round them to a height of fifteen feet. The ceiling was of stout planks, but there were three small openings, about eighteen by nine inches, in it, evidently for ventilation. There were no windows. These openings were covered by a strong barbed-wire mesh.

The short side of the building contained a small cookhouse and washing facilities. To get from the main room to these one had to walk through the courtyard in full view of the sentries. There were no connecting doors. There was only one window in the whole building and that was in the cookhouse. It was twenty feet from the ground and looked out on a street. It had four 1½-in. steel bars let into the stonework at the top and bottom. Transversely across them was a barbed-wire mesh, leaving a gap of no more than two inches. At first sight it seemed an almost impossible task to break out of such formidable barriers.

As soon as I got off the truck, the first person I saw was my "Stiffy." He was looking very angry. I didn't go over and talk to him ; for I was not sure whether they knew he was an officer or not. As people began to mix a bit I eventually got into casual conversation with him. All the more lightly wounded of my troop were here with him. Apparently they had all been taken to a hospital, fed, and well treated. The greatest blessing was that there was a tap with plenty of water. We simply couldn't drink enough after our days without. I thought we should now get some food ; for we had had none since we were captured. Not a bit of it ; the railway had been bombed and there was none available.

I volunteered for cookhouse and sanitary fatigues in my rôle of batman. I had to carry the swill some 500 yards outside the camp, and so was able to make a careful reconnaissance of the lie of the land. I was sure I could get away if once I got out of the building. As soon as I returned from the fatigues, I got hold of my two senior unwounded N.C.Os. and started them on the bars in the cookhouse window. As people were constantly coming in and out, it looked like being a long job. Meanwhile I got into casual conversation with a sentry on the pretext of asking about food. During our talk I gained a good deal of information : that the town was Emmerich, that we should probably be moved to Essen the next day, and that we were all shut up in the big room at night.

This was rather disconcerting, as it was essential to have access to the cookhouse. However, we had a conference, and made an alternative plan for using the small ventilators in the ceiling. The work on the bars went on slowly, while I planned the route on the map and checked our position by the sun. During the afternoon we got hungrier and hungrier, for we had nothing else to think about. I filled in some time trying to cleanse the now septic wound in my heel, for we had a long way to walk. During the late afternoon everything was cut and dried and we took it in turns to rest and work.

Towards evening Germans came in with some black bread and we were given two slices each. At 7.30 we tried the bars and found we couldn't move them ; they were stuck in the top. A frantic half-hour followed, as it was gradually getting dusk. We managed to loosen them sufficiently so that they pivoted on their top sockets, giving us about nine inches to slip through, between them and the wall. Fortunately another batch of prisoners arrived about this time, and we demanded bread for them. In the ensuing confusion we all managed to slip unobserved into the cookhouse. It was not yet dark enough to leave, so we stayed there for a quarter of an hour watching couples stroll by arm-in-arm.

At 8.30 I dropped down. The impact seemed terrific on the hard pavement. The other three followed quickly, and we started walking down the street in pairs. We didn't hurry, but sauntered along at the same pace as other couples. Eventually we got to a park on the outskirts of the town, where we halted. Having got our bearings we pressed steadily on. Away to our left, in a barracks, a loudspeaker was broadcasting a party leader's speech. The strident tones seemed to fill the night with sound. We had to go carefully ; for the whole area was built up and there were plenty of people moving about. It was early yet.

By eleven o'clock we had reached a housing estate. Here we met a check. There had evidently been some sort of party in the neighbourhood and several people were leaving. We had to cross the main road, and this was only feasible at one point. Here a soldier was saying good-night to a girl. I crawled stealthily up to them ; they were talking in low tones. I lay in the grass within a yard of them and listened-in cheerfully. It was really amusing to study this young man's technique. They kept it up for an hour, when a car came down the road with headlights blazing. It lit up all three of us. The couple were too confused to look down at their feet where I was lying. However, it discouraged them, and they parted shortly afterwards. This gave us a clear road.

We moved carefully through the housing estate and out into an orchard. Here we managed to get two apples each from a tree that had not been plucked. The country soon became more open and we could move faster, skirting villages and farms. By two o'clock on Friday morning we reached the frontier, which took us half an hour to cross, owing to the danger of discovery. It now became a matter of endurance. We kept up a steady four miles an hour, walking due west.

Friday

On the way there were two interesting incidents. About 3.15 I leapt blithely into a field and came face to face with a bull. He seemed huge in the starlight. He started pawing the ground in the most alarming manner. Then, letting out a bellow, he made a dash for me. I went over the gate like a swallow, and he crashed into it, nearly tearing it from its hinges. We could not be stopped by a bull at this stage ; so, seizing clods of earth and a stick or two, we re-entered the field. A running battle ensued as we chased the bull with cries and yells across the field, all thought of the Germans forgotten.

The country now became a series of open fields interspersed with dykes and wire fences. At one of these we had an unpleasant experience. I grasped the top wire firmly, and the next moment found myself gasping on the ground. It was an electrified cattle fence. Fortunately I had met a similar apparatus in Lincolnshire, and we soon disconnected it and continued on our way. About 4.15 we saw the gleam of water ahead, and in a few moments were on the banks of the Rhine.

We could hear a good deal of military activity on the southern bank. Soon we hit a road on the bank, and started moving down it. After a little while we came to factories and brickworks all along the bank. There were people moving about in them, getting ready for the day's work. By now we were so exhausted that we were beyond caring. We stumbled on and on down the road, and were so tired we could hardly see. All attempts at silence and caution were gone. We walked as fast as we could, knowing that if we stopped we would all fall asleep. My foot seemed to have been replaced by a ball of fire.

At last, about six o'clock, it began to get light. We stopped beside a big factory. There were two barges moored by the bank. Near them was a tiny wooden shed. I left the other three on the road and investigated. It seemed all right for us to stay in for the day. I called them, but there was no reply. I crawled laboriously up the steep bank and found them all lying in the road asleep. I woke them up and managed to get them down to the shed. It was filthy, but so were we.

The shed had evidently been used as a chicken coop. It had numerous spy-holes, through which we could observe. In size it was 8 by 6 ft. As soon as we were all in I carefully shut the door, but could not fasten it. By the time I'd done this they were all asleep again. I sat down and fell asleep myself, awaking with a start at ten o'clock. Two were snoring, so I promptly woke them and made them turn over. By now it was broad daylight. I observed the road on which there were numerous Germans moving up. They all seemed to be coming from a small town away to our west.

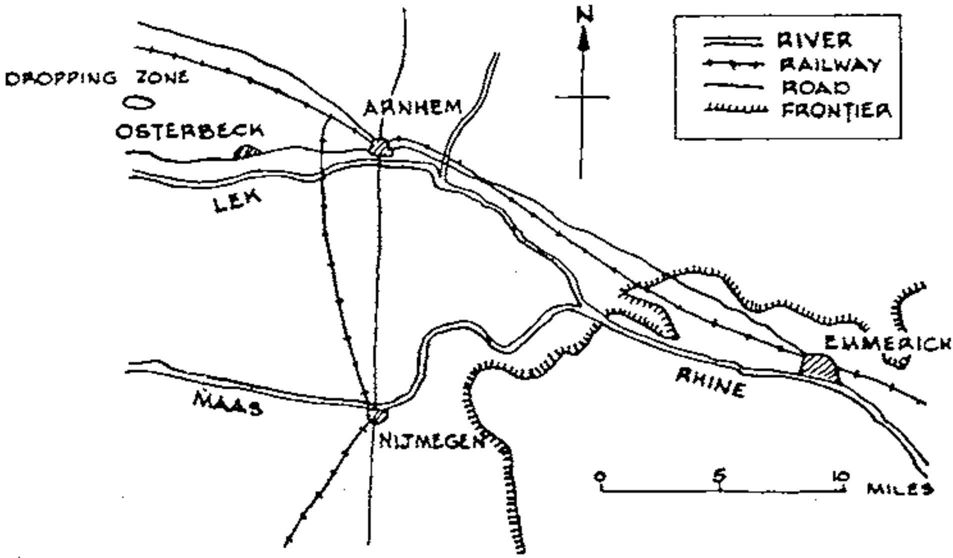
There was a lot of Dutch about, mostly on bicycles. On the barges beside us there was a certain amount of activity. One bargee's wife was doing the week's laundry. Our greatest trouble was to stop people snoring. On one occasion a soldier leant up against the thin walls of our shed smoking a pipe. We were no longer troubled by thirst as we had an apple each. It was apparent we should have to do the rest of the journey by boat. The night's march had been our final effort. The men's wounds were troubling them. My foot would no longer support me, and my bayonet wound had stiffened the top of my leg. In spite of our day's rest we were so weak from lack of food and the strain of the past few days, that we could walk no distance.

As soon as dusk fell we left the hut. During the day I had noticed a small boat tied up, down-stream. This we seized, while " Stiffy " and a corporal got on to the barges with their boots round their necks, and ransacked them for food. The owners meanwhile were listening peacefully to the wireless in another room. We brought the boat alongside and all embarked with the spoils. We had great difficulty with the boat, for it had no rudder and just one oar. At last we got it into mid-stream, where there was a good current running.

I sat up in the boat with our improvised rudder, while the others lay on the floorboards out of sight. We had not been going ten minutes when it began to rain. Very soon we were all soaked to the skin. A wind sprang up and we were driven on to the south shore. We extricated ourselves successfully and carried on, passing the town on our right. Various boats passed us and hailed me, to which I returned a cheery good-night.

Away to the west we could see Arnhem burning and hear the guns firing. The Rhine divides in two at this point ; half goes to Arnhem and half to Nijmegen. My greatest worry was lest I should miss the turning and go sailing into Arnhem. The river was so broad that I could only make out the banks with difficulty in the starlight.

Eventually it broadened out into a huge lake with numerous islands dotted here and there. I kept over to the left as much as possible, constantly checking my course with the compass. Suddenly a huge shape loomed up, dead ahead. I shouted, " Stand by to fend off ! " " Stiffy " and the corporals were galvanized into action, and we saved ourselves from being run down by a large boat. It would have sunk us if it had hit us.



SATURDAY

After this things quietened down. I just sat there and held the boat on its course. After we'd been going about seven hours, towards four in the morning on Saturday I saw a large bridge ahead. It was very similar to Arnhem bridge : but I didn't think it could be. I woke the others up, and we ran aground on the south shore. It was decided that I should go forward and see who held the town, we or the Germans. I was now able to walk ; for all feeling had been frozen out of my limbs by the wetting followed by long hours at the helm. However, caution dictated that I should crawl. Accordingly I wormed my way forward on my stomach. After I had gone some 400 yards I discerned some positions in the gloom. I eased over towards the nearest one till I was on the very edge of a trench. Here I waited till someone said something. At last I heard a snatch of English. I stood up and heard the welcome words, " Halt! Who goes there ? "

* * * * *

Anyone wishing to know more about the exploits of the 1st Parachute Squadron, should read Peter Stainforth's *Wings of the Wind.*

THE DHEKELIA PROJECT

By Lieut.-Colonel J. D. Edgar, A.M.I.C.E., R.E.

(*Author's Note.*—This article was written during the autumn of 1953, since when the author has left Cyprus and has been out of touch with the latest developments. Unfortunately, publication was delayed by various unforeseen circumstances and therefore some of the information may be out of date and expectations referred to may not have materialized.)

Introduction

WHEN Colonel G. A. T. Pritchard, C.B.E., left the appointment of Chief Engineer, Cyprus, in November, 1951 there was an interregnum period of five weeks before his replacement Colonel B. E. Whitman arrived. During this time the C.E's. staff produced, in the way of handing over notes for the new C.E., a lengthy but light-hearted document entitled "Dhekelia without Tears" describing in a fair amount of detail the history of the project up to that date, its main features and all outstanding problems. The start of the introduction of this document ran as follows :—

" Sir,

We with humble duty present you with this our baby, now to become yours. Conceived of G.H.Q. but as yet unborn, it is quickening in the vast womb of the War Office. Our prayers are fervent and united that it may, in course of time, attain full stature, having been attended at its birth and throughout its growth by its doting nursemaids, the contractors and supervising officers, and watched over by godparents too numerous and grand to name. It has had the best prenatal care ; no acreage of paper, no gallonage of ink has been spared that it should see the light of day sound in structure, fair of design and beautiful to behold. Suffering its share of childhood ills, it may deviate or modify, but we, its guardians, watching it grow will learn and, in learning, understand what not to do next time."

I quote this passage as its rather sweeping simile illustrates very fairly the sort of feeling everyone has towards the Dhekelia Project who has had any hand in its conception and birth. It is in all truth a baby and a vast baby at that. It is, with the exception of some adventures in India during the last century and, of course, the ill-starred Mackinnon Road project of more recent years, the War Department's first attempt to develop overseas on what was practically a virgin site, and on the most up-to-date town planning principles, a complete military township, with its residential and working areas, its town centre and its communal facilities. The site was not, as is usually the case, foisted on the planners to make the best they could of it, but was freely selected as being the nearest available approach to the ideal. So, being somewhat of a pioneering effort and under the force of other circumstances which will be described, it was inevitable that the baby should suffer " its share of childhood ills " ; in fact it has been thoroughly unruly and misbehaved at times ; but despite all, it is regarded with the greatest affection by the many Sappers and other sections of suffering humanity who have had anything to do with the planning or execution.

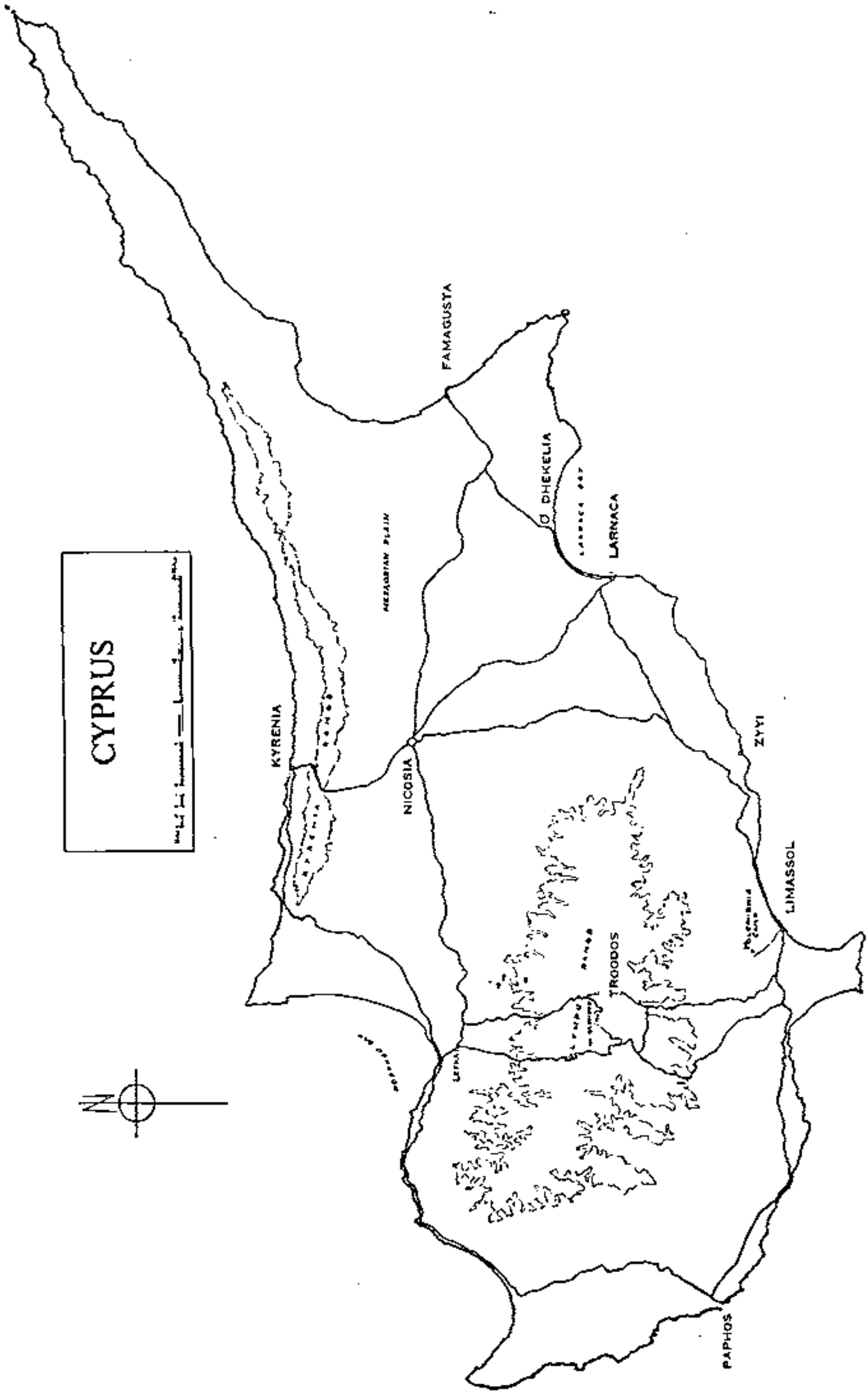
The Dhekelia Project is a very ambitious one ; in fact it is one of the most ambitious that has ever been undertaken by the War Department overseas in peace-time, and, if it can weather the many storms that undoubtedly lie ahead, as successfully as it has already weathered those of the past, it will provide the finest military cantonment that the British Army away from home has ever known. What has already been achieved could never have been made possible without the willing co-operation and hard work of many sections of the Army, in Cyprus, Egypt and the War Office, of a large number of civil architects and consultants and, last, but by no means least, of the Cyprus Government, of whom far too little mention is made in the pages that follow.

Many lessons have been, and are being learnt—in fact, we are all learning " what not to do next time." This account would, therefore, be a waste of time and paper if I did not attempt to bring out these lessons in the course of the narrative and summarize them at the end.

In trying to describe a project of this size and complexity I have found it virtually impossible to be strictly accurate. I have only touched on the main incidents and aspects that have arisen and have left unsaid many things that ought to have been said in a truly detailed history ; even those incidents that have been described have been dealt with in a rather impressionistic way, since if they had been treated as fully as history has dictated, the account would have rambled on interminably and interest and continuity would have been lost. So I offer my apologies in advance to all those with inside information and superior knowledge for any possible omissions and inaccuracies.

A Bit about Cyprus

As every schoolboy knows, Cyprus is a British colonial island tucked away in the top right-hand corner of the Mediterranean. It rightly belongs to Asia due to its position on the earth's surface, but 80 per cent of its inhabitants are definitely European in outlook, speech and religion, which makes it all very muddling ; suffice it to say that it is very definitely " Middle East." The climate is, of course, Mediterranean; that is to say, most uncomfortably hot in the


CYPRUS
FAMAGUSTA
DHEKELIA
LARNACA
KYRENIA
NICOSIA
ZYYI
LIMASSOL
TROODOS
PAPHOS

summer and very often equally uncomfortably cold and miserable in the winter, but usually blessed with perfect weather in spring and autumn. Reference to the map on page 328 will reveal that it is some 140 miles long and 60 miles wide at its widest.

The capital is Nicosia, which is also the seat of Government for most of the year ; when it gets too hot in the summer, His Excellency and his senior officials beat the traditional retreat to the mountains. There is only one respectable port, Famagusta, in which cargo vessels of up to 5,000 tons or so can berth alongside the docks. Limassol, Larnaca and Paphos are also so-called ports of descending degrees of importance, but they boast no deep-water quays and all vessels other than coastal schooners have to be served by lighters ; also their cargo handling capacities and customs facilities are very limited—although Limassol is about to undergo improvements which will very considerably increase its capacity.

Until the end of 1951 there was a single line, narrow gauge railway, with very antiquated " Emmetian " rolling stock, running from Famagusta, through Nicosia, to the mineral mines at Lefka. This has now been demolished as being uneconomical and the needs of transport are entirely served by roads. The main roads running between the larger towns are built and maintained by the P.W.D.; they are of different standards, varying from well-surfaced, 18-ft. carriageways to uneven, so-called tarmacadam of only 12 ft. carriageways with wide and very bumpy verges. However, as funds allow, the P.W.D. is carrying out a steady programme of road widening and improvement and the effect, even in the past two years, has been noticeable.

The island is divided geographically into three main areas. The whole of the western half is mountainous and wooded, the southern slopes of the mountains being devoted to vine culture. This is the Olympus or Troodos Range, Mount Olympus being the highest peak (6,400 ft.) and not to be confused with the Mount Olympus in Greece, the true seat of the Greek Gods ; Mount Olympus in Cyprus is merely the seat, in summer only, of senior Government officials and it would be both unwise and unfair to draw any comparisons between the two sets of deities.

Along the north coast running east from Morphou Bay runs the Kyrenia Range, a narrow ridge of hills varying in height between 2,000 and 3,000 feet and without doubt one of the most lovely ranges in miniature to be found anywhere on the earth.

The third division is the Mesaorian Plain, which simply covers that part of the island not covered by mountains. This plain supports most of the half million population of the island, is flat and largely treeless and such fertile soil as it carries is mostly devoted to the growing of wheat and barley, both of which are harvested in May and June. The result is that any visitor arriving by air in the island from July to September and seeing it for the first time, suffers a rude shattering of any preconceived notions of Cyprus being a beautiful island covered with trees and wild flowers ; all he will see is this vast, flat, featureless plain, brown and parched, shimmering in the heat of a sweltering sun with the hazy outline of mountains to the north and west. If, however, he is lucky enough to arrive in March or April, he will see fields still green with the unripened corn, interlaced with brilliant red and yellow carpets of wild flowers.

The main towns are a thorough mixture of eastern and western influences. The town centres consist of tangled webs of narrow streets, with sometimes a pavement 2 ft. wide on one side ; the buildings appear tumbledown and decrepit, with first storeys usually cantilevered out over the streets and the ground floors devoted to small shops filled to bursting with goods of every imaginable description. Large buildings of modern design, office blocks, banks, or large shops, are interspersed here and there and stand out prominently, highly incongruous in the surrounding somewhat medieval scene. The miracle is how sewage and sullage are disposed of, since water-borne sewage is unknown and yet the centres of the towns are all remarkably free from malodours, even at the height of summer. Away from the older town centres, we come on the more recently developed residential areas, laid out with apparently no regard to modern—or, in fact, any other—town planning principles : shacks built of mud, kerosene tins and rusty corrugated iron stand cheek-by-jowl with luxury hotels, blocks of flats and the more ordinary middle-class residences. The older type of house is generally Turkish traditional, of very simple rectangular plan, single storeyed with high ceilings and pitched roofs covered with hand-made half-round tiles. Since the war, and more particularly during the past three years, the spread of residential districts round all the main towns has been prodigious and the architecture, although usually maintaining single storeyed construction, has definitely adopted a more modern type of Mediterranean style, with smaller rooms, lower ceilings and very often flat roofs ; although this may have resulted in certain improvements in internal plumbing, it can hardly be said that the net result has been much of a gain. In the external decorative treatment of these houses, individuality is the keynote ; it is a matter of cliché, copyism, and pure experimentation and the results are sometimes startling.

The normal constructional material used is masonry, there being limitless quantities of first-class building sandstones and limestones in quarries scattered all over the island. A masonry wall 16 in. thick has most of the weatherproof and insulating qualities of a good brick cavity wall. Walls may be faced or unfaced, coursed or uncoursed, according to the degree of elegance required, but a rough faced 16-in. random rubble wall, pointed externally and plastered inside provides an excellent general purpose wall of reasonable appearance and cost. The more humble dwellings in the towns and mountain villages are built in 12 in. of uncoursed, unfaced and unpointed masonry. In the villages of the Plain, where the nearest quarry may be some miles distant, sun dried mud bricks are used. If these are rendered externally with a good lime plaster, such houses will withstand the elements for a surprisingly long time, despite the fact that such refinements as damp proof courses are practically unknown. The normal village dwelling, though, cannot even rise to a lime plaster and makes do with a mud plaster or no plaster at all ; even so, there are villages built entirely like this and they present a remarkably trim and neat appearance, blending in perfectly with the colours and contours of the surrounding countryside.

Cyprus is fairly prolific in indigenous raw building material, the main products requiring import being cement, timber and steel. Even so, a modern cement factory is under construction which will soon supply the island's needs and leave plenty over for export. Besides good building stones, there are limitless quantities of lime, gypsum and asbestos. There is a factory turning out high-grade gypsum plaster and plaster-boarding and another which produces a wide range of asbestos cement goods, including corrugated asbestos cement sheeting to " Continental " profile. Excellent Marseilles tiles are produced in Limassol which are in use all over the island ; competition and contrast are provided by the more traditional half-round Roman tile. These are somewhat crudely hand made and baked anywhere in the island where there is suitable clay, but there is one firm near Nicosia which turns out a very high quality uniform tile by machine. Another product of local manufacture and universal use in Cyprus is terrazo ware. This may be in the form of *in situ* work or precast floor tiles, basins, sinks, windowsills, fireplaces and goodness knows what else. In general, the floor tiles are excellent, cheap and decorative, but the other products, particularly the sinks, are not recommended.

Labour costs are, as one may expect, lower than in England, the average unskilled labourer earning about 12s. a day over a 44-hour week. However, his productivity is very much less, added to which the basic cost of building materials, especially those imported on to the island, is considerably higher ; there is, moreover, no cheap equivalent to the English brick, the nearest reasonable equivalent (discounting the mud brick) being 16 in. random rubble masonry, which is inevitably more expensive. The net result is that average building costs in Cyprus are some 10 per cent higher than in England for buildings of equivalent standard.

Not only is the productivity of the average Cypriot low, but his general standard of workmanship in any building department except masonry is appalling and requires the strictest supervision. Consequently any adventures in complicated reinforced concrete design must be treated with the greatest caution. Modern techniques such as prestressed concrete, or any non-traditional methods of construction such as "no-fines" concrete have still to make their appearance in Cyprus.

So much for the material and personal setting into which Dhekelia Cantonment was conceived. I have only touched on those aspects of the Cypriot scene which are relevant to the theme. Cyprus is a wholly fascinating island and there are enough points of interest worthy of lengthy description to fill many books. In fact, many such books have already been filled, so I'll say no more about Cyprus.

Mainly Historical

Before the war, the total Cyprus garrison consisted of one company of infantry, detached from a battalion stationed at Khartoum. This originally occupied a camp at Polemidhia, 4 miles north of Limassol, but after the 1931 riots in which Government House was attacked and burnt down, it moved to Nicosia. With such small numbers, there was, of course, no need for a complicated administrative set-up with Supply and Ordnance Depots, etc. But then came the war, and Cyprus soon became not only a bastion of the Eastern Mediterranean but also a convenient dumping and training ground for the theatre reserve divisions. As a consequence, administrative units and depots immediately sprang into existence at odd spots all over the island, mostly occupying land compulsorily leased from private owners ; erected for them were storesheds, offices and living accommodation all of the most temporary and makeshift nature, just about good enough for the duration and nothing else.

When the war ended, the garrison rapidly ran itself down till it consisted of H.Q. Cyprus District, one battalion of infantry and the remnants of all the administrative units, the latter still occupying their war-time glory-holes. Of all these, the only one sitting pretty was H.Q. Cyprus District ; this august body landed up in Wolseley Barracks in Nicosia, the home of the pre-war company of infantry, being a handsome collection of soundly built two-storeyed buildings. The worst off were the administrative units. Not only were these functioning in accommodation not at all conducive to efficiency, but also the War Department was having to pay through the nose for high rents, and in many cases the owners were pressing for early termination of the leases ; furthermore, the way they were scattered over the island meant administrative difficulties and waste of time and transport.

The post-war tension soon made it apparent that any eventual run-down to the pre-war garrison was out of the question, so the administrative units were here to stay. There was, therefore, a high priority Part I Service waiting to be got on with, to collect all these odd bodies into one centralized administrative area on land owned by the War Department where they would be housed in buildings specially designed to suit their individual functions.

Thereupon some pretty high level appreciating took place in G.H.Q., M.E.L.F., and a site was chosen 4 miles out from Famagusta immediately south of the main road to Nicosia. This site had certain obvious advantages: it was reasonably near the main port of the island; communications with the capital and therefore with the rest of Cyprus were good; the land was flat and well suited to the lay-out of depots; an adequate water supply was assured within a reasonable distance; the amenities of Famagusta and its magnificent bathing beaches would be within easy reach of the troops. The site was, however, somewhat bleak and desolate, with little or no topsoil or vegetation worthy of the name, blisteringly hot in summer and with no shelter from the winter gales. But this disadvantage failed to carry sufficient weight at the time; the site was accepted and planning went ahead with the meagre resources of the C.R.E., Cyprus.The future administrative area was christened St. George's Cantonment and, despite the somewhat hazy detail in which the project was planned, administrative approval was obtained in late 1949.

At this stage the gods stepped out of their machine with considerable effect. "G" came to a firm decision as to the strength of the peace-time garrison. It was also decided that this garrison should be accommodated with its full quota of families in permanent barracks especially built for its needs. The high level appreciators got busy again, but this time there appeared to be no problem for them to solve; the same factors that had guided their choice to St. George's for the administrative area once more applied, fortified by the further ruling laid down at G.H.Q. that the new cantonment was to be sited within five miles of the port facilities of Famagusta. So a site adjacent to St. George's Cantonment, henceforward officially known as Mile 4, was the obvious answer.

Now, obviously a project of this scope could not just appear on the ground without a great deal of preliminary planning and design work. So the question arose as to who was to do this planning. The C.R.E., Cyprus, was already somewhat overwhelmed by the burden of St. George's Cantonment, which he had to bear as well as his normal routine work with a normal C.R.E's. staff. In fact, all the resources at the disposal of the mighty G.H.Q. seemed equally unable to cope. A call for help was therefore sent to the War Office and the War Office responded promptly and effectively. A special branch was set up directly under the D.F.W., called the Cyprus Planning Team; in these early days, this consisted of a colonel, a captain and a clerk and occupied such vacant offices as could be found in an already very overcrowded Chessington. The head appointment was filled by Colonel W. F. Anderson, M.B.E., M.C., who had already gained some degree of experience in this kind of work when planning new cantonments in India immediately after the war.

The D.F.W's. Designs Branch, E.10, was at this time already heavily committed on planning various large scale development programmes both in U.K. and abroad and so, like G.H.Q., M.E.L.F., were unable to undertake this new commitment without outside assistance. Therefore War Office engaged the services of a well-known London architect, Mr. Alister MacDonald, F.R.I.B.A., as planning and architectural consultant for the Cyprus Project. Alister MacDonald had hitherto not been employed by the War Department, but he was soon to show how happy the selection was, by his ready enthusiasm for the project, maintained throughout despite all the difficulties and frustrations that were soon to confront him, and by his willing spirit of co-operation with the War Department, which, it must be admitted, proved at times to be a difficult and exacting client. His chief assistant was Mr. Edward Jamilly, A.R.I.B.A., Dip. Arch.,who was a war-time Sapper major and therefore conversant in some degree with the way the Army sets about doing things. Alister MacDonald decentralized the details of Dhekelia planning to Mr. Jamilly, who was put in charge of a new office in D'Arblay Street in Soho, employing twenty-four architects and draughtsmen full time and exclusively on Dhekelia.

So, in the spring of 1950, Colonel Anderson and his staff captain, Mike Hutton, accompanied by Alister MacDonald and Mr. Jamilly, visited Cyprus to have a look at the chosen site.

The M.E.L.F. brief was, by this time, reasonably firm as to what the new cantonment should contain and included were a new military hospital, to replace the tumbledown collection of war-time huts that were barely serving the purpose at Nicosia, married quarters to the authorized scale, District H.Q. and various amenities such as clubs, church, shopping centre, bank, post office, etc. In addition to all this, it must be remembered that the site, so far as G.H.Q. were concerned, was irrevocably fixed four miles outside Famagusta, south of the Nicosia Road.

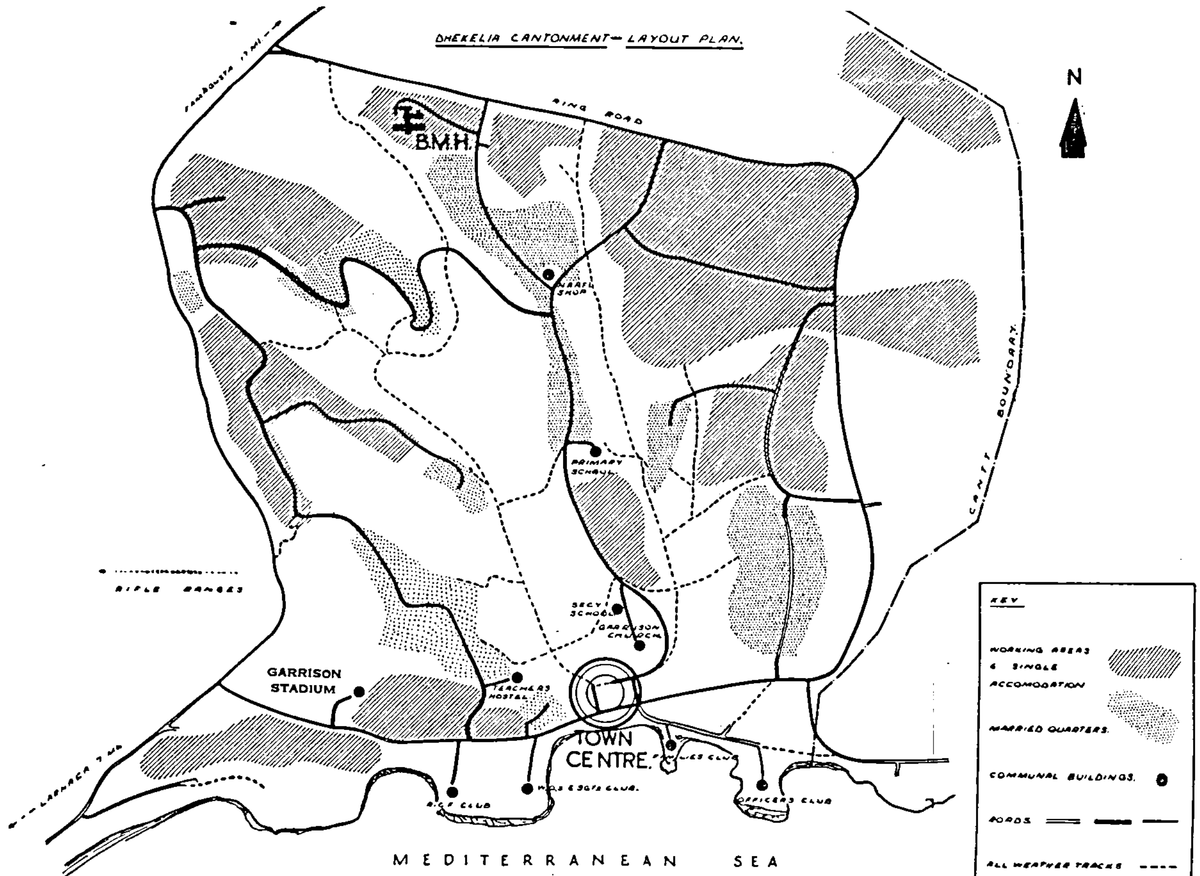
To this site, therefore, the planners first went and, with a completely fresh outlook and open minds, they found it not at all to their liking. They failed to agree with those at G.H.Q. that the bleakness and barrenness and general lack of charm of the site was a factor of insufficient importance to outweigh the rather more apparent and material advantages ; especially since Cyprus has a well-deserved reputation for variety and beauty of scenery. A tactfully worded letter was sent to G.H.Q. suggesting that the terms of reference of the team might be widened and that, while in Cyprus, the possibility should be investigated as to there being other suitable sites which might, on the whole, offer advantages over Mile 4. Since this did not necessarily commit G.H.Q. in any way, consent was given, but with the proviso that the administrative area must still be sited at Mile 4, since planning for this site was already well advanced. With this backing the team got busy. An " elimination map " was produced showing all the areas which, for one reason or another, were ruled out ; this, together with certain obvious " E," " Q " and financial considerations, reduced the number of possible sites to a reasonable quantity. All of these were visited in turn and at the end the team were left with no doubt in their minds that the Dhekelia site was the absolute winner.

On nearly all counts Dhekelia scored high marks ; furthermore, the site possessed considerable natural beauty and offered great possibilities for effective development. In the report which Colonel Anderson submitted to the War Office was included a full appreciation, prepared by Alister MacDonald, of the relative merits of the two sites (Mile 4 and Dhekelia) from the architectural point of view. In his conclusions to this appreciation MacDonald wrote : " Anyone who visits both sites cannot fail to be excited by the variety and beauty of the scenes which meet the eye at every turn at Dhekelia and make comparisons with the flat and tedious environs at Mile 4. The sea is surely the finest mental and physical tonic in a climate like that of Cyprus. One has a view of the sea from practically every building site at Dhekelia and the longest walking distance thereto is twenty minutes. One cannot see the sea at Mile 4 and the distance thereto is five miles.

" Even if the site at Mile 4 could be well landscaped it would still not have the same invigorating mental effect on the soldier as would Dhekelia. Boredom and its attendant evils would appear much more quickly at Mile 4."

The team returned from Cyprus firmly convinced that Dhekelia was the proper home, not only for the fighting troops of the garrison and for their families, but also for the administrative area which, it will be recalled, G.H.Q. still insisted should be sited at Mile 4. The team, however, hoped it would be possible to change this decision. Accordingly, Colonel Anderson's report presented three alternative schemes. Scheme " A " showed the whole at Mile 4 ; Scheme " B " showed the split with the garrison at Dhekelia and the administrative area at Mile 4 ; and Scheme " C " showed the whole lot at Dhekelia. Advantages and disadvantages of each scheme were discussed and the financial implications of each stated. The report was mainly factual and concluded with the recommendation, loyal to the G.H.Q. proviso, that Scheme " B " be adopted, despite the obvious and many disadvantages of the split.

However, the facts as presented spoke for themselves and War Office did not accept the official recommendation ; with remarkably little hesitation they ruled that the whole garrison, including the administrative area, should be housed at Dhekelia. G.H.Q. were persuaded that they would have to accept the consequent delay in the completion of the administrative area.



DHEKELIA CANTONMENT — LAYOUT PLAN.
N
B.M.H.
RING ROAD
NAAFI SHOP
PRIMARY SCHOOL
SEC'Y SCHOOL
GARRISON CHURCH
GARRISON STADIUM
TEACHERS HOSTEL
TOWN CENTRE.
W.O.s & SGTS CLUB.
OFFICERS CLUB
RIFLE RANGES
CANT BOUNDARY
MEDITERRANEAN SEA
KEY
WORKING AREAS & SINGLE ACCOMODATION
MARRIED QUARTERS.
COMMUNAL BUILDINGS.
ROADS
ALL WEATHER TRACKS

Planning Proceeds

The site and general scope of the cantonment were fixed by May, 1950, and before any further planning could proceed it was necessary for the whole area to be surveyed. The only survey in existence at any reasonable scale was the Cyprus Government 1/2,500 "cadastral," used purely for land registration purposes and of no guaranteed accuracy ; furthermore these sheets were not contoured, the only concession to land formation being the hachuring of very steep slopes. A contract was therefore placed by War Office with Air Surveys Ltd. for an aerial survey of the whole area to be carried out at a scale of 1/2,500, the actual photography being done by the R.A.F. From these photographs and before any ground control work had been done, this firm produced by June, 1950, a preliminary sheet at 1/5,000 which was reasonably accurate as far as position of detail went, but in which no guarantee was provided for the contours, these being no more than form lines. On this sheet two or three alternative zoning schemes were prepared and, after a considerable amount of high-powered discussion between the planning team and the various interested branches in War Office and M.E.L.F full agreement on zoning was eventually reached in August.

Jumping ahead a bit, the completed 1/2,500 survey sheets were ready in October, 1950, and shortly afterwards a further contract was placed with Huntings Aero Surveys to make a survey at 1/500 of all the building areas. Ground control work for this went forward in the early months of 1951 with the assistance of the local R.E., who cast and placed ninety-one concrete survey points over the area. All sixty survey sheets were completed, printed and distributed by October, 1951.

A brief description must be given here of the topography of the site. The ground rises away from the sea in three main ridges which join together at the north to form a more or less level plateau about 250 feet above sea level ; the valleys between these ridges are fairly well treed with carob orchards. A well constructed ring road system was also in existence, a very useful legacy from the old Illegal Jewish Immigrant Camp that was established in 1947 on the site of the new administrative area. (A less welcome legacy is the mass of old latrine pits which are considerably interfering with the building of the administrative area.)

Building development is in general planned on the high ground where the best views of the Mediterranean are obtained, and where the best advantage can be taken of the breezes in the hot summers ; another very strong reason for keeping development out of the valleys is that trees are scarce enough in the lowlands of Cyprus and it would be very foolish to clear treed areas for buildings when there is plenty of space available on the ridges where trees are few and far between.

Further points to note on the zoning (see layout plan, on page 336) are :—

(*a*) The general relationship of the married quarters areas with the various working areas ; the former lie as far as possible in the centre with the latter round the perimeter.

(*b*) The position of the Town Centre at the focal point of access from the rest of the cantonment and near the sea. The scale of the plan makes it impossible to show any detail, but it is intended that the Town Centre shall contain the following amenities :—

A terrace of twenty shops (with living quarters for tenant shopkeepers over).
N.A.A.F.I. emporium (extra synopsis).
Church (Protestant, non-denominational).
R.C. Church (site only at present).
Garrison education centre and library.
Cinema (air-conditioned, for all year use).
Church Voluntary Welfare Workers Club.
Ordnance officers shop.
Post office, banks and telegraph office.
Café.
Bus terminus and taxi rank.
Site for hotel.

(*c*) No development is shown north of the Ring Road. This is because zoning in this area is not yet finally settled and some installations remain to be sited.

In view of the urgent necessity for rehousing the unfortunate administrative units and to keep faith with G.H.Q., who had been somewhat forcefully persuaded to forego their St. George's Cantonment project, it was decided that top priority should be given to the construction of the administrative area. However, before any further planning could proceed, it was necessary for the planning team to pay a further visit to Cyprus, primarily to get first ideas on the master plan, and secondly to formulate some kind of basis of design for water supply, sewage disposal and the like. Therefore, in the middle of July, 1950, the same team as before flew out, fortified this time by Mr. W. S. Catlow, Senior Civil Engineer of the War Office, Mr. Trewin, Assistant Engineer, and two students on No. 2 Long Civil Engineering Course who were taken away from their respective consulting engineer attachments to be given the benefit of seeing the early developments of this mighty undertaking ; the two lucky names to come out of the hat were Major J. H. Fyson and that of the author. The senior members of the team, namely Colonel Anderson, Mr. Catlow and the two architects, stayed a little over two weeks during which time possible sources of water supply were investigated and a phased plan for their development outlined, the run of the main trunk sewer roughly aligned and the method of sewage disposal tentatively agreed, discussions held with the electrical authorities (the C.E.B.—Central Electrification Board, later to be known as the Electricity Authority of Cyprus, or E.A.C.) on the supply of power to the cantonment, the main framework of roads fixed and a rough layout of the administrative area produced. Which was not bad going in a temperature of 95 °F. every day. The remaining members of the party stayed on for a further two weeks chaining and levelling the pipeline from the Phase 1 water supply area, fixing the reservoir site, carrying out a tacheometric survey of the whole trunk sewer route and investigating the prevailing sea currents 150 yards from the shore. This last exercise was made necessary by the decision to dispose of the sewage by a sea outfall 150 yards out at the extreme south-west corner of the area.

Matters in the meantime had taken a big stride forward in another direction in the approval of the new appointment of Chief Engineer, Cyprus, on whose shoulders was to be the main responsibility for detailed planning and execution of the project. Colonel (now Brigadier) G. A. T. Pritchard took up the appointment in May, arriving in Cyprus at the beginning of August, 1950, with a very skeleton staff. Naturally enough there were no offices for him, so, until the necessary Nissens could be erected, he had to squeeze in with the unfortunate C.R.E., in his none too spacious offices in Nicosia. Eventually, after a number of setbacks, the C.E. was provided with a very fine set of Nissens near the C.R.E.—in Nicosia rather than at Dhekelia, as it was most necessary for him in the planning stages to have close liaison with H.Q. Cyprus District and the Cyprus Government. During the autumn and early winter of 1950, with little staff and no proper offices of his own, the C.E. was fully engaged on making the necessary contacts with the local military and civil departments and feeding back technical information to the centre of gravity of planning, which was still in London. However, December saw him in offices of his own and his staff complete in all the main appointments and the task of processing the planning was quickly shifted from the Cyprus Planning Team in the War Office to the C.E. Cyprus. This does not mean to say that the planning team was now allowed to die a natural death and fade completely out of the picture. Far from it, indeed. Dhekelia remained a War Office controlled project and as such there was a definite need for a close link between C.E. Cyprus and the many branches in the War Office who of necessity had to have a finger in the pie. Colonel Anderson, whose appointment was by now officially titled Senior Planning Officer (S.P.O.), therefore took on the functions of a sort of friend-in-court for C.E. Cyprus; he and his staff soon acquired an intimate knowledge of the workings of and the personalities in the various War Office branches and, by his equally intimate knowledge of the problems of C.E. Cyprus (maintained by frequent D.O. correspondence and occasional visits), it was possible for him to smooth and hasten the passage through War Office of not only "E" problems but also many "Q" matters, after these had arrived through the proper "staff channels." He could also maintain direct contact with the various branches (R.E.M.E., R.A.S.C. and the like) in progressing designs and briefs for the many technical buildings of the administrative area. Another vital function he carried out was in the engaging of, arranging terms of employment for, and maintenance of personal contact with the many specialist consultants that came to be employed on the project.

We have rather jumped ahead in our narrative and it is necessary now to go back to the middle of August, 1950, when the engineering portion of the planning team returned from Cyprus. The work done on the ground enabled preliminary designs for the first phase of water supply, main sewerage, storm water drainage and road construction to be worked out in some detail. In addition, preliminary sheets for the 1/2,500 survey started to arrive from Air Surveys Ltd. The first draft of A.F.M1428 for these external services was therefore prepared and sent out to C.E. Cyprus for his later use when required. At the same time, John Fyson working in closely with Jamilly and the various user branches in the War Office, prepared a detailed schedule of buildings in the administrative area based on Barrack Synopsis or special M.E.L.F. requirements. All this enabled the first estimate (*very* approximate) of the cost of the first contract to be worked out at about £1¼ millions. By some very brave extrapolation of this estimate, based on little more than inspired guesswork, a total cost of the whole project at £7.5 millions was arrived at. Needless to say, both of these figures were to suffer some very violent changes as time went on.

The planning team was still living rather hand to mouth as regards staff. No establishment had yet been approved and it still consisted only of the S.P.O., one staff captain and a clerk, all shown against the E.-in-C's. pool. The two attachments from the Long Civil Engineering Course were, of course, only temporary and came to an end in October when the course assembled at Chatham for its final fling—the author, however, got posted to C.E. Cyprus as S.O.II (Plans) and, pending his departure in January, 1951, stayed on with the planning team during November and December. E.10 were still too involved with other projects to undertake any of the detailed designs for the main external services. Messrs. Binnie, Deacon and Gourlay were therefore briefed in November to prepare working drawings for the water supply, sewerage and storm water drainage up to or away from the boundaries of the administrative area. (Designs of services within the administrative area would, of course, have to await the detailed layout of all the buildings.) The author was again extremely fortunate during this period in being loaned to Binnie, Deacon and Gourlay, who were themselves short of design staff at the time, where he was usefully employed in designing the

500,000 gallon reservoir. He was also able to provide useful first-hand knowledge of background detail, gained from his visit to Cyprus in the summer, to fill in gaps in the official brief. Incidentally, the terms under which this firm were engaged were unusual in that they were given no opportunity themselves at this stage to visit the site and make their own recommendations from first-hand knowledge of the conditions for solving the various engineering problems ; they were, in fact, asked merely to provide drawing office assistance and it says much for their spirit of co-operation that they were willing to agree to this. In actual fact, when considering the water supply problem, they did make certain recommendations which were by no means in accordance with the brief and these recommendations were accepted in full.

In the meantime, and as soon as the final survey sheets had been received from Air Surveys Ltd., the staff of Alister MacDonald had been pushing ahead with all possible speed on the preparation of the master plan. A master plan, for the benefit of those ignorant of the mysteries of town planning, is the next stage after the zone plan. It is usually prepared at a scale of 1/2,500 and shows the layout of roads and all individual buildings ; since it is probable that none of the buildings have yet been designed, the shapes shown on the plan are purely notional, the experience of the planner usually being sufficient to guide him as to the approximate size to be allowed. Of course, this master plan may bear little resemblance in detail to the final layout. As soon as the buildings have been designed as far as the sketch plan stage, by which time their shapes, sizes and aspects are known, the position of these can be accurately plotted at 1/500 and it will usually be found that the master plan layout can be considerably improved to give greater economy in roads, services, etc. However, the master plan is sufficient to show the over-all pattern of the layout and once this has been agreed, the planner is more or less free to develop the layout at 1/500 within the framework of this pattern.

To return to the narrative, by dint of much overtime the architects managed to complete the master plan by the beginning of December ; copies were thereupon flown out to Cyprus and G.H.Q., M.E.L.F. and a further copy circulated to the interested branches in War Office. On 14th December, 1950, a very important conference took place in War Office in which the master plan received the official blessing of all user services and, more important still, of Works Finance. It was the fond hope of the D.F.W. that this conference would see settled once and for all all questions of major scope. Alas for such hopes. Before ever a single turf was turned on the ground, the scope of more than one of the depots and unit zones had gone for a metaphorical six. I mention this in passing merely to point out the moral that it can be considered axiomatic in the Army that no decision, however high levelled, high powered and deeply considered, can *ever* be assumed to be really irrevocable. This, of course, is inevitable when it is remembered that our destinies are not controlled by a hierarchy of permanent civil servants but by staff officers of varying grades who hold their appointments for very limited periods.

Despite its ultimate failure to produce once-and-for-all finality on scope, the 14th December Conference did achieve a considerable measure of lasting agreement. The main framework was fixed, although some of its members were to be distorted subsequently beyond recognition, and inside this framework it was possible to build up the mass of briefing information which had to be supplied to the consultant architect before designs and working drawings could start to appear on paper. The most immediate result was the completion by the planning team of a most imposing document, a complete schedule of every single building that was to be built, with areas of all rooms worked out according to Barrack Synopsis and an estimate of cost of the building thereby arrived at—or, for non-synopsis buildings, costs that were considered reasonable were guessed ; it also included estimates for all the external services. This document thus provided a preliminary rough estimate (with accent on the "rough") for the whole project, which amounted to £8.8 millions and eventually produced approval-in-principle for the same sum in a War Office letter dated 23rd January, 1951. This letter, which by rights should have a certain amount of intrinsic historic importance, consisted of exactly two lines and was signed by a humble staff captain; it is to be hoped that this officer derived an amount of satisfaction appropriate to the importance of the occasion.

The spotlight now switches from London to Cyprus, where the C.E. Cyprus was just about this time getting into his full stride. All effort was being concentrated on the administrative area, which, it was hoped, would be out to contract in the summer of 1951. During December and January, not only the C.E's. staff, but virtually all the representatives of the specialist services (R.E.M.E., R.A.S.C. and R.A.O.C.) on H.Q. Cyprus District, ably assisted by an efficient and enthusiastic D.A.Q.M.G., were working overtime and in top gear churning out line plans and briefing material to enable Alister MacDonald to get on with the designs. In view of the extreme urgency of this part of the project (as it appeared to everyone at the time), with G.H.Q. pressing hard for their much-needed and long-delayed administrative area, War Office had laid down a very tight programme—briefing to be complete by the end of January, 1951, A.F. M1428 by mid-April, out to contract in early summer and start work in August—and the C.E. was determined that he, at any rate, would not be to blame if the timetable were not kept to. The first part of the programme, namely the line plans, was completed to schedule and it was now up to Alister MacDonald to prepare sketch plans, the first of which appeared even before the last line plan was dispatched. As soon as any sketch plan arrived a minor scurry took place. The plan was first rushed to the D.A.Q.M.G. for his approval and then to the appropriate member of the relevant user service ; finally, just to make quite certain, the D.A.D.A.H. was asked for his blessing, although in theory he was only interested if there were the remotest hygiene aspect about the building. Then comments on the sketch plan were sent off by priority signal " for D.F.W. for Cyparch," the latter being Alister MacDonald's telegraphic address for his Cyprus office. Such comments as there were, were mainly on the functional side ; aesthetic criticism was seldom, if ever, made even though some of the designs were perhaps a little unusual for the Army and lacked something of the massive and symmetrical dignity normal to War Department buildings ; but there was sufficient confidence in Alister MacDonald's artistic taste to allow him complete freedom in elevational treatment and let posterity judge the results. G.H.Q., M.E.L.F., took a parallel hand in all this. To save precious time, copies of the line plans were sent to C.E., M.E.L.F., and if they had any comments (which was rare in this early headlong rush) these were sent direct to Alister MacDonald (copy to C.E. Cyprus). In the same way, copies of all sketch plans were sent by MacDonald to C.E., M.E.L.F., who signalled comment to C.E. Cyprus in time for these to be included in the final signalled comments to Cyparch. Armed with these comments, Alister MacDonald's staff worked seven days a week and all round the clock on the working drawings, sometimes pushing these over to the quantity surveyors in the sketchiest form to enable the latter to get on with the bills of quantity. All was rush, rush and still more rush to achieve the target dates.

Here I must be excused if I digress for a bit to explain some special modifications to the normal works procedure that were adopted. Not even the most super-optimist could expect an architect to produce complete designs for some 110 different buildings, the quantity surveyors to produce B.Qs. for all these and all the roads and external services to be designed (and billed), all for tender action on a contract worth some £2 million, to take place only six or seven months after the starting pistol. So two major streamlining modifications were made to the normal procedure. The first was that the contract should be prepared in detail for about three-quarters of its total value ; " fixed " bills would be prepared for the roads and all the services, but for only a limited number of buildings, which were specially chosen to give a fair representation of all types of building work that would be used in the contract ; such buildings as were not yet designed would be included in the contract as provisional lump sum items and would be priced later on in accordance with suitable rates extracted from the other bills. The second modification was that the contract was allowed to go out to tender *before* approval-in-detail had been given. In fact, the A.F. M1428 was sent off from Cyprus only three weeks before tendering action took place in London. It should be mentioned here that all contract action was undertaken by War Office and tenders were put out to U.K. firms only, in view of the fact that the contract was well beyond the capacity of any Cypriot firm.

The first contract went out to tender on 29th June, 1951, and everyone surfaced for breath, proud, certainly, of a somewhat momentous achievement, but at the same time conscious of a certain uneasy feeling that things had been rushed too much, too little checking had been possible in the time and that there was a heap of trouble in store when work on the ground actually started. But plenty of work in the office remained to be done. Alister MacDonald and his staff of Dhekelia architects under Jamilly had to press on with the designs of all the remaining buildings which featured as provisional sums in the contract, and there were many loose ends to be tied up, particularly in connexion with the external services. However, the extreme sense of urgency had gone and planning thenceforward proceeded at a more leisurely pace ; the luxury of letter writing was resorted to instead of trying to say everything by signal, which very often arrived corrupt ; working drawings could be properly completed and checked before being passed to the quantity surveyor for billing ; the C.E's. staff in Cyprus were able to take some much-needed leave ; in fact, life became easier all round for everybody. But there still remained headaches and heart-aches, caused mainly by the fact that the 1428 was now undergoing the normal routine processing in the War Office—in other words, it was being subjected to the most searching scutiny by many different branches of the many interested services. Now the first fruits of that mad rush earlier in the year were harvested. Few buildings escaped this microscopic examination unscathed ; some buildings in fact, had to be scrapped almost completely and Alister MacDonald supplied with entirely fresh briefs ; such buildings were usually the more technical ones, such as the bakery, or the instruments repair shop in the R.E.M.E. workshops, the initial briefs for which had been supplied in the first place by C.R.A.S.C. and D.A.D.M.E. respectively in H.Q. Cyprus District ; not being technical specialists in these departments, these officers could hardly be held to blame—the fault lay in the fact that the briefs had not been checked at a higher level right at the start ; but of course there wasn't time. Smaller pinpricks, but nearly as troublesome in the long run, were all the minor errors discovered in the original briefs, sometimes due to misinterpretations of ambiguous wording in Barrack Synopsis and sometimes just mistakes.

Tenders were received back in the War Office in early September and were subjected to the normal careful examination which lasted till the middle of November. All was then ready for signature and only awaited approval-in-detail. The A.F. M1428 had in the meantime been tidied up and knocked into shape and all outstanding points of detail had been settled. All, in fact, was ready for the curtain to rise on the first scene of the first act at Dhekelia after eighteen months of hectic preparation.

Now came anti-climax ; the expected approval-in-detail for Dhekelia, Phase I, failed to materialize. But, to borrow a phrase from the language of international diplomacy, this did not mean that the door had been completely closed to further progress. Funds were still forthcoming with which to pay our outside consultants' fees, which meant that further planning could still go ahead. The project was officially suspended pending a world-wide examination of all works services, but it was by no means dead. So full advantage was taken of the ensuing lull to complete the unfinished designs of the administrative area and to tie up many loose ends in the first contract which were still floating around. Also planning, briefing and designs went ahead at a more orderly tempo for the other zones of the cantonment. But as the months went by with still no news of approval of the first contract, hope steadily dwindled among the original members of the C.E's. staff that any of them would see the fruits of their early and enthusiastic labours. Every visitor from the War Office was eagerly questioned on the latest situation and we took such comfort as we could from the news that Dhekelia was still definitely "on", that it was reaching higher and higher spheres of consideration and that even a very important personage had written a minute on the subject (presumably praying someone to let him have a history of the project on one sheet of foolscap). The military correspondent of a great and reputable London daily paid us a visit and wrote a very heartening article for his paper, describing in graphic detail the natural beauties of the site and the ambitious way it was to be developed, but at the same time deploring the apparent stagnation that had set in and urging the authorities to let the project proceed—but, of course, to no avail. The summer of 1952 blistered its way through July and August with still no further news and, with other major projects in Cyprus of top rate importance looming heavily over the horizon, interest in Dhekelia dwindled to a very low ebb.

Financial Blizzard

During all this time, no one really knew how much the whole project was going to cost. We have seen how some rather vague estimates were produced out of the blue in the early days when there really was not much to go on. The priced tender documents for the first contract, which the War Office had had since September, 1951, provided the first realistic basis for a comprehensive estimate, but a proper analysis of all the prices and their application to the remaining buildings and services of the cantonment was a mammoth task which no one in War Office had yet had time to tackle. The latest figure to come out of the bag was one of £14.7 millions, but this could only be considered as a rough indication of cost based on some very approximate and rather pessimistic calculations, and, until a more reliable figure could be worked out, it had to be used as the basis of all discussions on the future of the project.

Of course there were alibis for this apparently high figure—high cost of developing a virgin site, higher building costs in Cyprus, larger room sizes permitted for a sub-tropical climate, etc., etc. ; but making due allowance for all these, the cost still appeared far too high under the financial circumstances in which the country found itself. Furthermore, it must be remembered that approval-in-principle had been given to the project some eighteen months previously when it was thought that it was only going to cost £8.8 millions and it was a shock to those in authority to hear it was going to cost some £6 millions more.

However, early in September, 1952, the news leaked out that Dhekelia would receive final sanction provided the ultimate cost was kept to £10 millions ; on 15th September, approval-in-detail for the first phase was given at £2,100,000 and all was almost set for the starting whistle—almost, but not quite, since the final estimate for this phase came to £2,268,000. (The tender price was actually very much lower than this figure, but the cost of W.D. supplied stores had to be reckoned with and also the tender, it will be remembered, included provisional sums for a lot of the buildings and these were all very much on the low side.) So, before the contract could actually be signed, two things were necessary ; first, see if the contractor was willing to stand by his tender figure, now twelve months old, and secondly decide how £168,000 was going to be lopped off the contract. The contractor raised no difficulty over the first, the V.O.P. clause in the contract largely taking care of any rises in costs during the past year. Over the second, one suspects that War Office and G.H.Q. spent a happy afternoon with a big red pencil. Five complete buildings were eliminated from the contract, their construction being postponed till more prosperous days had arrived ; our precious district heating scheme (which will be referred to later) went overboard and the whole policy of space heating was drastically modified. These economies were reckoned to account for £155,000 ; the final gap was closed by a general lowering of specifications and a little moderation in the good quality finishings that had been specified. War Office were thereby satisfied with the rather hopeful assurance that the first contract could be done for £2,100,000 and the contract was at long last signed on 3rd October, 1952.

But there still remained that horrible problem of reducing the cost of the whole project to £10 millions. Obviously the first thing to be done was to arrive at a more realistic estimate than the inspired guess of £14.7 millions. Major Otway had recently joined the Cyprus side of the planning team (having previously spent many months planning an abortive project elsewhere in the Middle East) and he was immediately saddled with this unenviable task. He tackled it with enthusiasm and energy and produced his first answer of £12.7 millions early in October. He brought this out to Cyprus the same month and various details were argued, thrashed out and modified. During the ensuing weeks letters on the subject flew between Nicosia, Fayid and Chessington, which all quite bewildered the unfortunate Caesar Otway, and each such letter that reached his " in " tray caused a different figure to appear. Thus, in about ten weeks, no less than seven different answers were produced, ranging from £12,275,000 to £13,350,000. At this stage, luckily for Caesar's sanity, interest in the subject waned and the latter figure was the one finally accepted on 17th December. Whether all this herculean labour was productive of anything more realistic than the previous guess of £14.7 millions is debatable, since it was of necessity based on many assumptions, some of which were themselves highly debatable. Thus, an arbitrary figure of 7½ per cent was allowed for possible increases in costs during the ensuing years. Secondly, the cost of all buildings was worked out on cube rates of similar buildings which could with reasonable accuracy be priced from the first contract ; but this was rather extravagant extrapolation since unit costs of some ten different types of building in the administrative area had to be applied to the vastly more varied types of building that were to be erected elsewhere in the Cantonment. Thirdly, practically nothing was known of the scope and complexity of the external services in future phases and again an arbitrary percentage figure had to be applied on the costs of the buildings themselves. Fourthly, no account was taken, or could be taken, of the possibility of severe inflation setting in consequent on this and other large-scale military developments in Cyprus. Lastly, no one could say with any assurance that the first contract rates would be truly indicative of future contract prices ; tender prices may have been highly competitive or even sacrificial in this contract to enable the contractor to establish himself on the island. This, of course, is all very different from large-scale estimating in the U.K., where cube rates can be accurately assessed to within a fraction of a penny and where statistical graphs showing variation in costs over a number of years in all aspects of building work are readily available to the estimator. In Cyprus, on the other hand, nothing like this has been attempted before by the W.D. and the contractural system normally employed in private building, which omits the services of a quantity surveyor, does not enable building costs to be closely analysed.

Anyway, there on the one hand was the best estimate that could be produced, namely £13,350,000, and on the other hand there was the financiers' limit of £10,000,000. To close this gap, drastic steps were needed.

By eliminating a number of buildings altogether, by once again abandoning district heating in the various zones, by redesigning barrack blocks from two-storeyed buildings holding seventy-two men to three-storeyed ones holding 108 men, by general reductions in specifications, by reducing on synopsis scales wherever possible and by fixing ceiling prices on certain of the more expensive kind of buildings, War Office hope to have closed the gap. But who knows? Who can possibly tell till the project is far more advanced than it is now? It can only be hoped that in two or three years someone will write a further article on Dhekelia giving up-to-date news on building progress and the latest state of the finances.

The First Contract

On 3rd October, 1952, the first contract was at long last signed. The successful tenderer was Sir Lindsay Parkinson & Co. Ltd., working in association with the Cypriot firm of Titan Construction and Engineering Co.

A word must be said here about the executive organization that was set up for the control of the project. As I have said before, the only works organization in existence in Cyprus when Dhekelia was first thought of was one C.R.E., who, with the aid of a D.C.R.E. in Nicosia and another in Famagusta, was responsible for all normal services in the island. It was patently obvious that he could not be burdened with a further possible annual expenditure of some £2 million at Dhekelia. However, from the early days in the summer of 1950 to the actual start of work, commitments on the ground were not heavy, consisting mainly of planting and watering some 20,000 trees and shrubs and carrying out the many necessary preliminary engineer investigations on and around the site, practically all of which were suitable jobs for D.E.L. Consequently, during this period, an independent D.C.R.E. working directly under the Chief Engineer was all that was required. But, when during the winter of 1951/2 it looked as if the first contract might start any day, it was realized that a considerably stronger set-up than one, or even two, D.Cs.R.E. was required and an establishment was therefore worked out for a highly compact and powerful C.R.E. organization; I say "compact" since the area of responsibility was itself compact and it was therefore possible to achieve a high degree of centralization in accounting and paper work, thereby giving D.Cs.R.E., G.Es. and C.Ws. far more time on the ground than they usually manage to achieve; it was also powerful in that it included an S.Q.S. and so many contractural tangles could be sorted out on the spot without having to be referred to higher spheres.

Throughout 1952 the establishment of C.R.E. Dhekelia was argued over, thrashed out and rewritten several times over by Captain L. H. Dawson, the C.E's. hard-worked personnel officer. It was eventually approved and promulgated in December of that year, taking effect as from 9th October. It may be thought that twelve months or so was a long time to produce an agreed establishment for such a humble organization as that of a C.R.E., but that was only part of the whole story. The state of affairs in Egypt during 1952 suddenly elevated Cyprus into a position of considerably higher strategic importance than it had occupied before and as a consequence major developments were proposed and intensive planning took place to cater for certain eventualities. These were well outside the potential of the Chief Engineer as he existed at the time. So *pari passu* with the setting up of a C.R.E. Dhekelia came the need for a complete overhaul of the whole Works Establishment in Cyprus. It was this that delayed matters and caused so many revisions.

The contract, as I have said, was signed in the War Office on 3rd October and it was not long before contact was established between the Chief Engineer and Sir Lindsay Parkinson. This firm was fortunate in already having in existence an organization in Cyprus, in fact, right on the site, because immediately to the east of the cantonment they had just completed a contract for the new Cyprus power station. Accordingly, they simply moved their site staff from one job to the other, a matter of half a mile, and the agent for the one became sub-agent to the other, holding the fort till a more senior man was imported as chief agent. The managing director flew out and a preliminary meeting was held in the C.E's. office on 20th October in which generalities were discussed. The site was handed over on 1st November and the first sod turned on 24th November. " Turning the first sod " is perhaps a misnomer since a compressor was in fact used and what should have been a notable event was somewhat marred by heavy rain.

Although the contract and, in fact, the whole project was at long last fairly launched, it was still operating on only one cylinder. Neither the home team nor the opposition had much more than the nuclei of their respective organizations on the ground. As we have seen, the C.R.E's. establishment was not approved until December and the appointment of C.R.E. was itself only filled on 16th December when Lieut.-Colonel Clayton Warth arrived from England. The first batch of working drawings were received on 27th October, containing details of site layout, all external services and a very few of the buildings. Thereafter drawings, bills of quantity and particular specifications kept arriving at irregular intervals throughout the next six months, until by about the end of May over 900 different drawings had been accumulated, which nearly, but not quite, accounted for the sum total ; drawings for the sports pavilion and reduced boiler house were actually not received until well over a year after the contract had been signed. Furthermore, although all B.Qs. were received in their bare state at much the same time as their respective working drawings, pricing the bills of all the "provisional" buildings (carried out in War Office) was a long and tedious business and even at the time of writing (October, 1953) many of these still remain to come. As nine copies of each drawing and document had to be sent to Cyprus to satisfy the varying needs of contractor, C.R.E. and C.E., the total freight tonnage amounted to something quite considerable. All this, of course, was the inevitable aftermath of last-minute changes to bring down the cost of the contract, necessitating almost complete revision of many of the buildings. Luckily the size and nature of the contract made it very flexible from the contractor's point of view and it is doubtful whether, in fact, the speed of progress suffered very much as a consequence.

In addition to the disorganization to the planning of the execution of the work, this piecemeal and late receipt of drawings, B.Qs. and specifications meant that it was impossible for the site supervisory staff to study the documents in detail before work on the building affected was started. Such was the pressure from the contractor (natural enough under the circumstances) that when drawings, etc., for any particular building were received in Cyprus (and seen for the first time by either the C.E's. or C.R.E's. staff) it was quite usual for that building to be set out and excavation started within one week. Which meant that any difficulties and snags that were encountered from day to day, due to errors or omissions in the drawings, discrepancies between drawings and B.Qs., etc., had to be solved on the spot or progress on that building was held up.

In defence of our architects and surveyors let it be remembered that both were working under fearful pressure in the early days of planning to complete sufficient bills to meet the War Office target date for tender, and therefore the time factor militated against careful checking; furthermore, the fifteen months or so that elapsed between the contract going out to tender and being accepted was entirely taken up in completing the designs and bills for the "provisional" buildings and our hard pressed consultants never found a real opportunity to go back and check their former work. Since it was mainly these "fixed-price" buildings that were ready at the start of the contract, it was these buildings on which work first started; so it was inevitable that these depressing difficulties should be encountered right from the start. Queries which could not be sorted out on the spot began piling up in the early months of 1953, and correspondence between C.E's. office and that of Alister MacDonald became more and more involved and less and less amicable until early April when Alister MacDonald judged the situation sufficiently serious to warrant a personal visit. He flew out with two members of his staff and personal contact once more put our relationship on its normal footing. His two assistants stayed at Dhekelia for three weeks, sorting out the details of all our queries, while he himself spent rather a shorter time in Cyprus getting acquainted with the background of all our difficulties and discussing general and particular details of the future. We received his assurance that similar difficulties were unlikely to occur over the "provisional" buildings, since it had been possible to give very much greater care in their checking. And so it has proved in fact. Any small snags that have arisen since that date have been easy to sort out on the spot, or, at the worst, have required a simple query to London to which a simple answer has been quickly given.

Another worry of considerable nuisance value assailed us in the early summer of 1953. With buildings beginning to materialize on the ground, it was natural for the various user services to take a renewed interest in their respective depots and installations. However, it was very annoying and not very constructive when those same services started saying, almost with one voice, that the layouts and arrangements in the depots were quite unworkable, the buildings were all the wrong size or shape and they would not be doing their duty if they permitted work to proceed in the manner planned without official representations on this, that and the other. Sometimes they had some justification for their complaints in that circumstances had arisen since the depots were originally planned, which had altered the use to which they would be put. (Even so, how many functional buildings used by the Army are put exactly to the use for which they were planned ?) In other cases the only reason was that the local head of the service was not the same man as the one who had approved the layout and plans originally, and it was a case of a different individual having different ideas. Every effort was made to satisfy our clients and, where work had not yet proceeded too far and where there seemed to be some justification for a change, the case for alterations was put up to higher authority. But where this necessitated increase in expenditure, which was almost invariably the case, this was either turned down flat or else the delays incurred in getting the new requirement approved were such that work would already have proceeded too far by the time authority had been given. We could not, of course, tell the contractor to stop work on any particular section pending the result of these representations, which might take months to come through, as this might have resulted in claims from the contractor for delays, disorganization to the work and extra overheads. And so, in nearly every case, these last minute interferences produced no result whatsoever other than a lot of wasted paper work. Once the wheels of the mighty works machine have been put in motion, it is virtually impossible to start altering it or adding to it in any way.

When the first contract was at last signed, it was considered that the start of the largest single project ever undertaken in Cyprus should be suitably dignified by an official foundation stone ceremony. After some initial delays, it was eventually arranged that the ceremony should be performed by His Excellency the Governor, Sir Andrew Wright, K.C.M.G., C.B.E., M.C., as a part of the official Coronation proceedings in the island. There wasn't much time ; His Excellency was due to leave Cyprus about 21st June on leave and we got our first official notification less than a month previously. Luckily, a design for the foundation stone had already been prepared and only awaited His Excellency's final approval, and also the officers' mess, the only building in the administrative area with sufficient dignity to incorporate this important emblem, was at little more than foundation stage and with a bit of intensive overtime could soon be brought to the requisite degree of preparedness. The date was finally fixed for 15th June and the two associate contractors (Sir Lindsay Parkinson and Titans) entered into the spirit of the occasion wholeheartedly. Sir Lindsay Parkinson contributed the stone itself and a silver trowel (afterwards presented to the C.R.E's. Mess) and also arranged a very lavish display of decoration and bunting, provided by the joint efforts of Lieut.-Colonel Warth and Captain Dawson ; Titans paid the extra over specification for the very high quality masonry wall in which the stone was set and presented a handsome silver salver and bouquet to Lady Wright. The ceremony was attended by all army, civil and government officials (and their wives) who had had anything to do with the venture and the proceedings went off without a hitch. Speeches were made by His Excellency and the District Commander (Brigadier S. R. Garratt, C.B.E.), the stone was blessed by the Senior Chaplain and His Excellency impressed everybody with his manipulation of the trowel and mortar ; in fact his standard of workmanship was such that the stone did *not* have to be raised and relaid afterwards, as is usually the case, or so I am told. Repercussions in the local Greek press were very mild and there were no subsequent political upheavals, as at one time had been feared.

(*To be continued.*)

NUCLEAR ARMS AND THE SERVICE MAN

By Colonel T. I. Lloyd, D.S.O., M.C.

THERE is long continuing discussion on the functions of the Services in this atomic era. Navy, Army, Air Force, Merchant Service—and an era : how great a theme ! But in the end it will turn on one simply expressed requirement, which is that the functions must be humanly possible. For any service is primarily a collection of human beings, and unless we study first, and then remember all the time, the peculiarities of man, more especially such of them as can be expected to come to the surface in nuclear warfare, we shall certainly go astray in our argument.

Humanly possible. This is easily assessed in terms of muscle and endurance ; it is determinable empirically at least, when human control of a complex machine is in question ; but, beyond the realm of the tangible, the phrase is full of uncertainties which have been explored only a little, and scarcely at all in a nuclear context.

How will man behave in nuclear warfare ?

The tendency nowadays is to leave any difficult question like this to the scientists or—since there is some doubt about psychology as a science—to the psychologists. But surely, knowing our own minds at least as thoroughly as any psychologist (we hope), we are under some obligation to try to worry it out for ourselves. We might set about this on the following lines.

First, taking the worm's eye view of nuclear warfare, we single out the one transcendent characteristic of an atomic airburst—and perhaps this will be enough for our entire purpose. It is that *an atomic burst cannot miss.*

At once the strategist or higher tactician questions this, illustrating his point with coins on a chart or map. So we explain to him that for the time being we are not in the least interested in his fleets, formations, or groups of airfields, which may survive in part. We are as one solitary man, trying to visualize atomic bursts and decide what behaviour they will induce in us. We occupy at the very most a dozen square feet. A nuclear burst strikes a zone of square miles : solidly, like a gigantic steam hammer or power press, flaming hot, missing nothing. And our greatest personal peril used to be the bullet of cross section .07 sq. in.! Or perhaps it was a shell or bomb fragment not very much larger. In any event, O Strategist ! permit us to be perturbed.

The last—and only—time we were confronted with a war hazard of this kind, reducing us to infinitesimality, was on 22nd April, 1915, when the Germans first used gas. The gas cloud, flowing along down wind, couldn't miss. It was a roller rather than a hammer, and erratic with the wind, but the analogy is not altogether too pale to serve.

How did man react on that occasion? We can take pride in remembering that within a very few days—aided by external factors such as the improvisation of respirators, the limitations of the weapon, German ineptitude, and the vagaries of the weather—he had steeled himself to meet the threat; but the fact remains that on 22nd April, 1915, man ran—"from Ypres to Dunkirk."

Surprise came into it, and there are men and men, but the way in which on that April day whole units and formations dissolved in the face of the irresistible—or seemingly irresistible—cannot be ignored. A lot of things suddenly ceased to be humanly possible, perhaps because:—

"In the face of gas, without protection, individuality was annihilated; the soldier in the trench became a mere passive recipient of torture and death. A final stage seemed to be reached in the whole tendency of modern scientific warfare to depress and make of no effect individual bravery, enterprise, and skill. Again, nearly every soldier is or becomes a fatalist on active service; it quietens his nerves to believe that his chance will be favourable or the reverse. But his fatalism depends upon the belief that he has a chance. If the very air he breathes is poison, his chance is gone: he is merely a destined victim for the slaughter."*

Degrading is perhaps the word for the experience these men underwent. It seems that human beings are infinitely degraded by the close menace of some foul, lethal thing, immeasurably bigger than themselves, against which there is no defence. It revolts them, and saps their very essence, so that they almost cease to belong to the higher, reasoning animal group—or if they do reason they all come to the same conclusion. They turn from the thing, instinctively, blindly, just as any healthy individual turns from vain suicide.

If, on the other hand, the menace can be brought within bounds, its only effect may be to increase the fury and savagery of the fighting; such at any rate was the sequel in gas warfare. A Canadian division put up a stout defence against the second gas attack only two days after the first, and by 2nd May a gas attack had actually been repelled—a memorable action for the Dorsets.

Is there any possibility of the atomic menace being countered like gas, or being in any other respect confined within reasonable bounds, so that men may face it as men and continue their allotted rôle within the function of their service?

Certainly there is at least one possibility of bounds being imposed, though whether, under the particular circumstances envisaged, they will appear reasonable to us is another matter, for the bounds con-

* From pages 153-4 of *A History of the Great War* by C. R. M. F. Crutwell, who mentions that he himself was in the trenches south of Ypres in April, 1915, where a gas attack was constantly expected though not experienced.

templated will have been imposed by the enemy, on himself, voluntarily. It will be conventional war with one, strictly limited, nuclear element. Two possible examples of this type of warfare will now be given.

Our first example will comprise the employment of nuclear weapons for blockade purposes. Sea blockade has often, we remind ourselves, achieved, or come desperately near achieving, the full war aims of a combatant power ; and since, for geographical reasons, one contestant is normally more susceptible to it than another, it is unlikely to be proscribed by international agreement in advance of all war being so proscribed. We, of all peoples, shall do best to take it into account in studying future war.

Suppose that the blockader decides to use his nuclear weapons for the purpose, but at the same time solemnly undertakes not to employ them elsewhere than over the high seas, never striking the hostile mainland, nor even its coastline, and never, accordingly, risking the fulfilment of current prognostications about nuclear war wiping out whole populations and civilizations.

Under these circumstances it is conceivable that the blockaded nation and her allies will hesitate, for a period at least, before retaliating against the blockader's cities, or indeed against his territory anywhere ; for that sort of retaliation, they can be sure, will be met in kind—the gloves will be off. So the situation envisaged may not be too fanciful ; in any event it is imaginable, which is all that matters here, where we only need a nuclear background against which we can see—and measure—ourselves, and perhaps decide whether we, in the rôle of ordinary service men, will be able to carry on some function allotted to our service.

This form of blockade would mean that day and night, at a frequency depending on our enemy's nuclear resources, bursts would be occurring off our shores, close enough to imperil coastal shipping, not close enough to cause damage on land. Sometimes our enemy would have means of reconnaissance, or other intelligence, enabling him to detect targets ; at other times he would fire blindly into the coastal zone ; if manned aircraft were still in vogue for atom bombing they would come on opportunity missions.

As passengers or, more pertinently, crew members in ships or aircraft arriving or departing, how should we feel about running the gauntlet across the danger zone—say, a hundred miles wide ?

Well, we reflect, once we cease to be landborne nothing worse can happen to us than sinking into the sea. The risk of this was considerable throughout two world wars, and it was faced steadfastly. Does it matter if the form of sinking alters, becoming perhaps more horrific ? A sudden cataclysm may even seem preferable to being shot down or torpedoed in the Atlantic in winter. Again, does it matter that there is no chance whatsoever of hitting back effectively at a guided missile ? Often in the world wars the chance of hitting back must have seemed, to the men most concerned, negligible.

We can go on like this, questioning and reassuring ourselves, but at the back of our minds all the time will be the thought : " Which way are the odds ? " By nursing this thought we tacitly admit that at some level of odds, well short of certain death, we shall expect to be allowed to remain landborne. Furthermore, if we are in the higher ranks we shall expect, at the critical level of odds, not to be required to order others into the danger zone. The function of our service must be possible humanely no less than humanly : Paschendaele was a long time ago.

Now, in this particular setting, if it is prolonged, the odds will accumulate greatest against the merchant seamen ; naval craft will be more resistant than merchant ships ; submarines will be least affected. Accordingly it is perhaps as a merchant seaman that we should ask ourselves how we would react. After one escape, which has given us a close view of ships that did not escape ; with the seaward bombardment continuing ; the whole country flashlit from varying directions, and atomic clouds billowing up from the horizon, many times a week ; would we, or would we not, say to ourselves, " the submarine service for us," or even " the coal mines " ?

In our second example of limited nuclear warfare the contestants are neighbouring countries, but between them lies a wide desert ; the aggressor is coming across it ; his lines of communication will in due course traverse it. A desert, like the high seas, constitutes a clear atomic target area where civilians and civilization are not in hazard. So there will be nothing unreasonable in the defender, or conceivably some third power interested in restoring peace, announcing that the desert will be treated as a field for nuclear warfare, on the same terms as the high seas in the previous example.

It might have been interesting to put ourselves first in the shoes of the aggressor commander-in-chief or government on receiving this ultimatum ; but we are here concerned with humans, and judging from the events of this century the heads of aggressor states are not cast quite in human mould : we could never be sure of following the workings of their minds. In this particular instance we'll just presume they persist, without retaliating ; and so the war becomes nuclear, but only over the desert.

Let us first put ourselves in a tank, in the spearhead of invasion, running the gauntlet across the desert. We have gained surprise and a flying start ; for the present there is no ground opposition and we have tremendous air support, so that no bombs threaten us, only guided missiles—from heaven knows where, though ; our tank gives us fair protection so long as we are not altogether too near ground zero. In our minds we are fanatically determined to right some imagined wrong to our forefathers, and—perhaps most potent of all—we know that once we are across the desert we shall be safe, comparatively. Also we look forward to getting to grips with the people who have unleashed these weapons. Yes, we'll drive on, while we survive. Our task is humanly possible : the function of the armour is to that extent feasible.

Next let us consider a slightly later phase in the war, and deem ourselves employed on the desert lines of communication, as vehicle driver, crew member of a transport aircraft, or working number in one of the many static establishments needed on any lines of communication. Nuclear attack on the desert continues ; we have seen its effects.

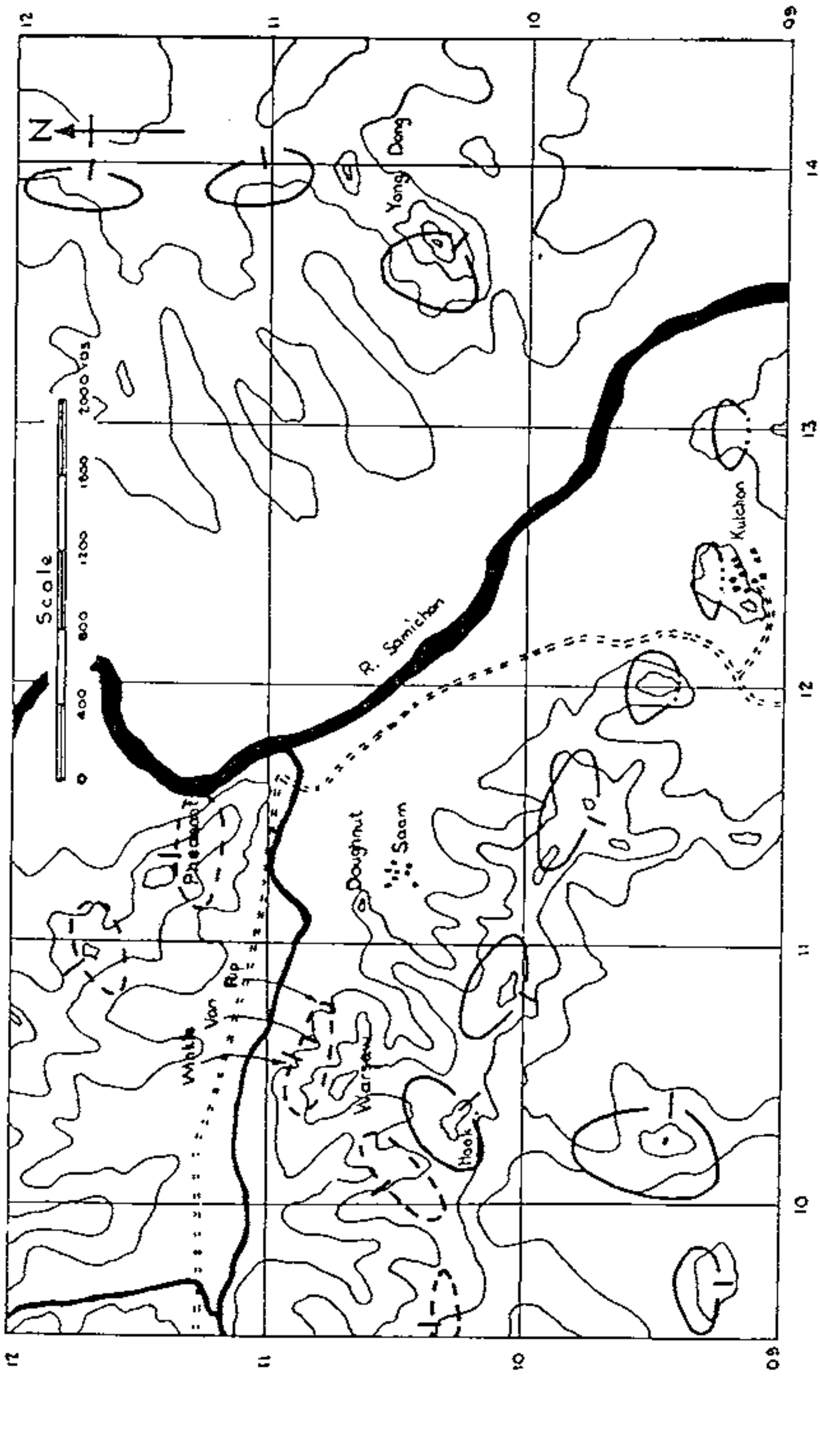
Whence can we draw the inspiration that enabled the armour to win through ? Our tasks are humdrum, and the odds mount against us as we repeat our crossings or continue to dwell in the danger zone. Meanwhile the " teeth " are having, we think, an easier time. Possibly we of the " tail," in anticipation of this ordeal, were recruited from tougher material, and trained in a tougher school. In any event, as in the blockade example, there will be some critical level of odds.

The examples we take will always resolve into a question of odds. These should be calculable, at least approximately, for particular circumstances, by teams of planners and scientists ; and it seems not illogical that this process should be carried out at first in respect of limited nuclear war, as typified in the examples given : when the domestic kitten—to employ a famous metaphor—has become only a half-grown tiger.

Then must follow the decision on what is humanly possible, and what is not. Suppose that at this stage we ourselves are consulted, as ordinary service men, in regard to the critical level of odds at which our unit can be relied upon to continue to function—to return to the danger zone ; to march towards the sound of the (atomic) guns. One direct hit destroys it physically, we know. How many near misses shall we say are required to destroy it morally ? Does a near miss really miss ?

Once the services are satisfied that they will contain no non-starters in restricted nuclear war then will be the time for them to turn and consider functioning in full-scale nuclear war. Meanwhile they have, of course, ample field for study in conventional warfare. They must not get rusty at that : it still may happen, and it always was difficult enough.

There is also, of course, the national problem of *surviving*, as distinct from functioning, in full-scale nuclear warfare. It again will be difficult enough, but luckily the solution need not run counter to human nature.



Contours at approx 150 Ft. intervals

RIP VAN WINKLE

By Captain G. L. Cooper, M.C., R.E.

Introduction

THIS article tells the story of a raid on Chinese-held positions in Korea on the night 4th/5th June, 1953. Sappers from 55 Field Squadron were involved and the raid, though not in itself a great success, had far-reaching results and also provided several useful lessons. These lessons may be old ones relearnt the hard way, but if we always knew the answers beforehand we would always be successful, something alas which does not happen too often in either war or peace. The story and the lessons therefore may be worth repeating.

Planning

For six weeks the Chinese had been trying to dislodge the 1st Commonwealth Division from the "Hook," an important salient on the left of the divisional front. They had made two fierce attacks on it in that time and it was thought that they might well make a third. This was borne out by air photographs which showed that the Chinese were digging close in to our positions, particularly on the reverse slopes of "Warsaw," an enemy feature about 250 yards north of the "Hook." This digging took the form of tunnels and they were similar in appearance to the ones dug at the end of the previous year for troops to lie up before the November battle with the Black Watch. One important difference with these new tunnels was that they were constructed in some steep re-entrants at the back of the feature and were defiladed from our artillery and also from our tanks on "Yong-Dong" to the east. The Brigade Commander was getting increasingly worried by these tunnels and decided that the time had come to destroy them.

On the evening of 2nd June, No. 1 Troop Commander was brought down to earth from his Coronation festivities by a phone call from the squadron 2 I.C. telling him to be in the command post at 2200 hrs. for an "O" group. A warning was also given that he would be wise not to let his men celebrate too much in the canteen. At the "O" group the O.C. informed him that there was to be a raid the following night on "Warsaw" with the aim of destroying some fifteen tunnels in three re-entrants to be known as "Rip," "Van" and "Winkle." A frontal attack was not considered practicable and the Brigade Commander had decided to attack from the rear by making a long detour from the east. Troops taking part were to be "C" Company, 1 Kings, and an Engineer party of one officer and fourteen O.Rs. from No. 1 Troop, 55 Field Squadron.

There was not much time to prepare before the raid so preliminary arrangements were made that night for the supply of satchel charges, extra automatic weapons and all the other items that would be required. Next morning there was a briefing by the C.O., 1 Kings, followed by a rehearsal of the attack so that everyone could meet and sort out some of the inevitable problems that would arise. It was realized that it would be a great advantage to carry out a ground recce first as nobody quite knew what they were up against and they would be covering ground which they did not know, so the Brigade Commander agreed to a twenty-four-hour postponement, as recces could not be made in daylight. That night two recce parties went out, the first to find a route through the wire in the valley and the second, consisting of an infantry officer and No. 1 Troop recce sergeant, to try and get behind " Warsaw " and see how large the caves were.

In the meanwhile quite a lot of thought was given to the preparation of the demolition charges. The sappers would have to carry 20 lb. of explosive through some 4,000 yards of hostile territory. The ready-made satchel charge consists of 20 lb. in 2 lb. T.N.T. blocks, contained in a canvas bag with a strap. This is bulky and awkward to carry. An added difficulty was that it was expected, and subsequently confirmed, that the tunnels would be quite shallow, as it would be of more advantage to the enemy to have several small ones instead of one large one from the point of view of ease and speed of digging. These shallow tunnels might be rather difficult to blow as the blast would tend to blow straight out at the entrance and do little damage. This was overcome by having a small tamping charge at the entrance and the main charge right inside. The ordinary light-weight pattern haversack proved an ideal satchel and was easy to carry on a man's back with the normal attachments. Twenty pounds of plastic explosive fitted conveniently inside. Charges consisted of two 8-lb. charges, each with a 2-lb. tamping charge connected by 20 ft. of Cordtex and with a 30-sec. delay initiation. In the case of a large tunnel the plan was to open the quick release clips on the haversack, extract a small charge and the Cordtex and throw the haversack into the tunnel, holding the small tamping charge at the entrance. In the case of a smaller cave, the charge was split in two on the site and two caves were to be dealt with in a similar manner.

The reconnaissance to the back of " Warsaw " was very successful and confirmed that there were numerous tunnels, though they had not been able to get near enough for inspection. The re-entrants were occupied by Chinese and in fact the party had been nearly captured. They had also found a suitable area in the stream-bed to lie up prior to the attack. The extra day and the additional information gave plenty of time for rehearsal and for practising the sapper party in splitting and placing their demolition charges.

The outline plan for the attack was that troops taking part were to form up in the company locality at Kulchon (124092) and proceed along the track leading north towards "Pheasant" and to turn west up the valley at approximately 120103. A firm base consisting of Company H.Q. and one platoon was to be established on the knoll, "Doughnut" (113106), and three fighting patrols and a forward control group composed as follows were to go forward again from there :—

(*a*) "Rip" : one Officer and twelve O.Rs. plus one N.C.O. and four sappers.
(*b*) "Van" : one Officer and twelve O.Rs. plus one N.C.O. and four sappers.
(*c*) "Winkle" : one Officer and twelve O.Rs. plus one N.C.O. and one sapper with the task of right flank protection and opportunity destruction of caves in that re-entrant.
(*d*) Forward Control Group : one Officer and twelve O.Rs. plus one Officer and two sappers.

The track from Kulchon passed through three minefields and when the raiding party branched off they would have to gó through a tangle of old wire fences across their path, the remnant of the previous years fighting. The Assault Pioneer Platoon was to clear a path through this wire, mark it with white tape and luminous discs and guard the exit at the far end. The narrow track necessitated everyone moving in single file. From there on, the valley was littered with scattered, uncharted, nuisance minefields of both sides and the whole area had been constantly shelled for long periods.

As the whole object of the raid was the destruction of the tunnels it was most important that the sapper party was not encumbered unnecessarily. Every man therefore carried only a Sten gun and grenades, with a pack on his back containing the charges. They were also given instructions that should anyone be wounded on the way in to the attack the others must not stop to help, but leave the person to be picked up by the infantry.

The Raid

The men formed up at Kulchon soon after last light and were ready to move off at 2200 hrs. The O.C. came to see them off and chatted quietly with the men in the darkness. Everyone was naturally pretty nervous and was glad when the time came to move off. The Troop Commander caused some light relief by omitting to blacken his face until the last moment when there was only black boot polish available, provided with some amusement by the infantry C.S.M.

The Assault Pioneers had moved forward at last light and cut the wire and marked the route to the far end of it, where they then took up a defensive position. The platoon to form the firm base was the first of the main party to move off at 2200 hrs. followed closely by the Company H.Q. and the three fighting patrols. Company H.Q. was large and rather cumbersome as, in addition to its normal complement, it had a Gunner forward observing officer (F.O.O.), a mortar fire controller (M.F.C.), the forward control group, and two signallers reeling out an assault cable with a field telephone. With a manpack 62 set and the various other wireless sets, it seemed to make an awful lot of noise. Communication between each party was by 88 set with 31 sets for the F.O.O. and M.F.C. and a rear link to Battalion H.Q. provided by the 62 set and the field telephone.

It was a pitch dark night as the moon would not rise until 0200 hrs. and movement forward was slow. Enemy were reported close to the exits from the wire and two men were wounded by grenades. Progress was even slower for a while until the company 2 I.C. moved forward into the lead. The whole party then moved on fairly steadily along an ill-defined and overgrown path and were approaching the ruined village of Saam when a man just in front of Company H.Q. trod on a mine killing three men and wounding twelve. Some thirty men must have passed over the same spot before him.

These casualties and the men required to evacuate them considerably depleted the assault parties. This necessitated an immediate alteration in plans and the Company Commander decided to form a firm base where he was and to send the fighting patrols, now formed into one, with a much reduced control group, straight to the stream bed and to attack and destroy the tunnels in " Rip " only. Two of the sapper assault parties were thus left at the firm base and helped to protect it. The prospect of success with so few men did not look too promising.

At approximately 0200 hrs. the assault party left the firm base and moved with all speed through Saam, skirted " Doughnut " which they found was unoccupied and, under cover of artillery, slipped into the bushes beside the stream and moved closer to " Warsaw." With grenades and a mine going off in the valley the main Chinese positions on the hills must have quickly become aware that something was happening so the divisional artillery kept up a barrage to prevent them reinforcing their positions or moving into the valley. The guns, including tanks, also fired on " Warsaw " to keep the enemy's heads down.

A small bund ran about ten yards from the stream and this provided a convenient feature behind which the Control Group could take up a defensive position, while the assault party covered the final 150 yards to " Rip." The infantry were to lead the assault closely followed by the sappers. As they moved up the re-entrant they were to deal with any enemy found, throw grenades into the tunnels and take up a position above the farthest tunnel until the sappers had placed their charges. They were then to withdraw, the sappers pulling their igniter switches as they accompanied them, and to pass back through the control group who would cover the withdrawal to the firm base. Speed was essential.

By the time the assault party was ready for the final dash the moon was well up but there was considerable smoke due to the continuous shelling and mortaring and it was difficult to see.

The tanks on " Yong Dong " were firing on fixed lines with their 20 pounder tracer shells into " Rip," " Van " and " Winkle " and, though they could not destroy the tunnels, they served as a useful indicator of the direction in which to move.

As soon as the guns stopped firing the assault went in. The first tunnel was grenaded and passed, but then opposition was encountered and some close quarter fighting took place. The Chinese were there in force and used Burp guns and stick grenades. Several men were wounded and went back to the control group where they were told to make their own way to the firm base. Opposition in " Rip " became too heavy and the assault party found they could make no further progress ; two more wounded returned to the control group and told them that the attack was being beaten off. The officer in charge of the assault party was forced to order a withdrawal and he himself dragged Sapper Harris, badly wounded in the thigh, to the bottom of the re-entrant, covered by Sapper Smythe. Smythe then returned to the first tunnel alone, threw his satchel charge inside and pulled the igniter switch, successfully destroying it. He then rejoined the officer at the bottom of the slope and helped to drag Harris to temporary safety in some bushes.

Meanwhile, the control group was waiting anxiously beside the stream. They waited as long as possible to cover the withdrawal, but were frightened of being cut off and eventually had to leave. No sooner had they started to withdraw the way they had come than the leading men found that in fact they had already left it too late and were surrounded. They immediately cut across the stream, moving north as far as they dared towards the main Chinese positions and then east to the stream again. The stream was nearly waist deep and they had difficulty in getting some of the wounded across. On the far side of the stream this small party regrouped before moving on.

Just then Sapper Smythe rejoined them, having come by himself from " Rip." They had been unable to move the wounded Harris further, so Smythe gave the officer his Sten gun and set off for help, completely unarmed. Unfortunately the control party consisted of only nine, of whom five were wounded so nobody could be spared. The Troop Commander gave Smythe his Sten gun, as he also had a revolver, and Smythe, without a second's hesitation, returned to try and find Harris.

The control group party eventually got back to the firm base by a different route and found that the Assault Pioneer Platoon had moved up. A small party from them was sent out to try and find

Harris and the officer, which they did, the officer, 2nd Lieutenant Williams, having managed to drag Harris on his own to a place of comparative safety where the rescue party found them. Smythe had missed them in the dark and after searching the foot of the re-entrant, by this time swarming with enemy, he made his own way back to our lines. He later received an immediate M.M. and the officer the M.C.

At the firm base preparations were made for casualties to be evacuated and for everyone to withdraw. It was now about 0430 hrs. and beginning to get light. Unfortunately just as the withdrawal started another mine exploded wounding five men. Smoke was put down by the gunners to cover the withdrawal and as the company moved down the track to Kulchon, Centurion tanks moved forward in case the enemy should follow up behind. The whole company was back by about 0600 hrs.

Retrospect

The first lesson to be learned is that cut and dried preparations must be made for the evacuation of casualties incurred in the approach march before the actual assault. The operation should not have been crippled by the casualties caused by mines. The casualties themselves were comparatively unavoidable, but the use of the assault force as stretcher bearers was not. It is virtually impossible to find scattered mines on a dark night and in ground that has been heavily shelled, where electronic mine detectors are useless and prodding is too slow, added to which is the difficulty of knowing when and where to start looking. Scattered nuisance mines are one of the normal hazards to be expected and overcome in a night attack of this nature involving a long march through hostile territory. That every casualty that night was brought back is a great tribute to the determination of the British soldier not to leave his comrades, but those incurred on the approach march should have been carried by men from a reserve platoon, e.g., the Assault Pioneer Platoon and not by the assault party which was thus seriously depleted.

The second lesson to be learned is that the firm base must not be too far forward in relation to the total distance involved. "Doughnut" was the ideal place for it, but it was over three-quarters of the way to the objective and as it turned out it was never reached as a firm base. If it was to be used, then a shorter route to it should have been adopted, e.g., down the spur from the south. The route to the firm base must be secure and if this cannot be done then it must only be as far forward as can be reached safely. It might well have been better for the sappers to have proved the route to a firm base and for the assault pioneers to have carried out the destruction of the caves.

Another lesson learnt was the value of wireless. By having a F.O.O. and M.F.C. at the firm base, close and accurate fire was maintained by means of wireless. But in the assault parties, only one 88 set out of five was operational, the other operators being either wounded or temporarily lost in the confusion. A wireless operator with headphones on is a very helpless individual, particularly at night, and he must be closely looked after if he is to give his full attention to sending out and receiving messages. It is also useful to carry a spare 88 set aerial as they are easily lost where the going is rough, and in fact this operator eventually lost both by the time he returned to the firm base.

This raid, though not successful in destroying all the Chinese tunnels resulted in heavy casualties to the enemy and their abandoning the " Warsaw " re-entrants, evidently for fear of being attacked in the rear. It also resulted in no further attacks being made on the " Hook."

ROYAL ENGINEERS IN BERLIN IN 1954

By Major D. J. Willison, M.C., R.E.

GONE are the days when Berlin was full of Sappers, when vast and intricate demolitions made the headlines and when Berlin weathered the Russian blockade. For all that, the tasks of the Royal Engineers to-day in the city remain as varied as ever despite the much decreased strength of the Corps in Berlin. Apart from Movements and Postal detachments with Berlin Independent Brigade Headquarters, the remaining engineer elements are grouped in a composite unit called Royal Engineer Troops Berlin. This is an unfamiliar Corps designation which might mean almost anything. In fact it includes a small headquarters controlling a standard field troop, a D.C.R.E. works and two garrison engineers, an E. & M. element containing a substantial mechanical equipment park, and a stores depot.

Before giving some account of the multifarious activities of this composite unit, it might be of value to describe the appearance of and conditions in Berlin in the year of grace 1954. The three Western Sectors are now governed as an entity by the West Berlin Senat, under the direction of the Western Military Commandants. East Berlin has its own administration which sits in the old Rathaus of the city. In addition the East German Government, also operates from the East Sector. Despite this, the Western Occupation Forces have full rights of access to the East Sector, as legally the Russians have never officially abandoned the quadripartite control of the capital of Germany.

The contrasts between the Western and Eastern portions of the city illustrate most vividly the differences in the mental approach between the two great power blocs. In West Berlin the general impression is one of piecemeal rebuilding, where architectural styles reflect the varied facets of private enterprise at work in a free economy. Marshall Aid has been devoted primarily to rebuilding factories and large blocks of workers flats in the traditional, rather ugly, tenement style. In East Berlin the overwhelming impression is one of drabness and uncleared rubble, relieved only by the standard window dressing of a Communist dictatorship. The show piece is Stalin Allee, a dual carriage-way avenue of outwardly impressive workers' flats which is, no doubt, an exact replica architecturally of many to be found in Moscow, Stalingrad and other great cities behind the Iron Curtain. Marx Engels Platz, which stands on the cleared site of the old Kaiser's palace, provides the vast parade ground flanked by gigantic propaganda hoardings, which seems to be an essential element in the Communist way of life. For the rest, huge slogans supported by red flags slash the front of all large buildings which remain standing.

Shops in East Berlin are almost all state-owned ; the mystic letters HO appear above most window displays. These are by no means impressive and the contrast with those to be seen in the glare of neon lights of every hue down the Kurfurstendamm in West Berlin is most striking. At Treptow the Russians constructed a garden of remembrance to the Russian soldier, in which many of the reliefs and statues are of some intrinsic value. Much of the material, however, came from stripping Hitler's Reichschancellery and other public buildings in the East Sector. By contrast, in the British Sector only one very small memorial stone at the end of the Autobahn exists to commemorate the path of 7th Armoured Division from the Desert to Berlin. A recent task of the Sappers has been to arrange renovation of this memorial, using money from Divisional funds.

West Berlin remains a beleaguered city in that all food, raw materials and consumer goods have to be imported from the West and all manufacturers have to send out again, some of them even now by air. Since the riots of 17th June, 1953, in East Berlin, travel to and from the City has been reasonably free from interference. Canal, rail and autobahn all take their share of traffic with the zone. For the occupation forces in the Western Sectors the normal means of transport is by rail, though passes to travel on the Helmstedt autobahn by private car present no difficulty. The writer even obtained from Karlshorst a Soviet " propusk " to travel down the Leipzig autobahn to Bayreuth and Munich last January. The journey of 190 miles behind the Iron Curtain was accomplished without incident and much courtesy from the Russian frontier post commandant who had not seen a British officer and family for three years. The visitor to Berlin has to obtain permission from the local headquarters at least a fortnight in advance, but once this has been obtained, travel by road, rail or air presents no particular difficulty.

It is not often appreciated that the three Western Sectors enclose a considerable area of forest and lake besides the main built-up area of the city and its suburbs. The perimeter round the three sectors measures some ninety miles and it is possible to drive nearly thirty miles in a straight line from the extreme north of the French Sector to the southern limits of the American Sector. Within the British Sector good facilities can be found for engineer training which would suffice for at least a squadron, let alone a troop. The Havel presents a magnificent stretch of water, nearly ten miles long and a minimum of a quarter of a mile across. Barring the lack of current and the obvious difficulty of bridging right across so important a barge thoroughfare, excellent watermanship and rafting training can be obtained from the hard and prepared bankseat at Dachsberg. There is an excellent demolition range in the Spandau forest, with a safety zone of 1,000 yards all round. A valuable field works and mines school has been built up over the last few years in Smuts Barracks, where the unit now shares a barracks with the 1st Independent Squadron R.T.R. There is ample room within the barrack area for a fieldworks ground, which is now being developed.

The Field Troop in Berlin is most fortunate in that it is kept fully up to strength, an almost unique occurrence in these days of F.F.C. reviews but clearly essential for so small an independent unit. Once the attitude of mind that the troop existed to carry out odd jobs on a no cost basis had been dissipated, it has been able to turn the available training facilities to good advantage. Brigade and Inter-Allied exercises astride the Havel provide an opportunity for the troop to show its skill in the arts of watermanship and rafting and every opportunity is taken to practise co-operation with tanks and infantry during the summer training season. As exercises are not so numerous as in the zone, there is much more time to improve the standard of field engineering. In the late autumn of 1953 five junior N.C.Os. and sappers succeeded in gaining their field engineer class two rating.

Throughout the summer, pioneer platoon courses of six weeks duration for each of the three battalions in the city keep the Q.M.S.I. on establishment very busy. In winter all arms mines courses, on which French and American officers and N.C.Os. sometimes participate, are run. In all these courses, junior N.C.Os. from the troop assist the Q.M.S.I. in the practical instruction. To round off the collective training of the troop as a whole this year, it is planned that they should move by road down the autobahn to Western Germany where they will take part at full strength in a divisional exercise under the wing of 27 Field Engineer Regiment.

Turning to the works services side, the great task of the last year has been the rebuilding of the Sportshalle, beside the Olympic, Stadium, to house both the Military and Control Commission Headquarters for Berlin together with ancillary units. Coupled with this has been the rehabilitation of Smuts Barracks, Spandau, to take R.E. Troops Berlin and the 1st Independent Squadron, R.T.R. This large project costing nearly £500,000 was substantially completed between March and December, 1953, final billing being cleared by the middle of March, 1954. The constant headaches caused by a large number of both military and civilian organizations repeatedly changing their requirements as work proceeded can be left to the imagination. Other major new capital works have included a new sewage works for one of the battalion barracks situated right on the zonal border and a large scale central heating project covering the barracks occupied by R.A.S.C. and the R.E.M.E. workshops.

The maintenance problem in Berlin is a particularly heavy one, in that the works services are responsible for all premises occupied by the Control Commission for Germany, in addition to all strictly military buildings and installations. Garrison Engineer East in fact looks after such variegated properties as the British Consul General's house, the British Council Centre in the Kurfürstendamm, and the Norwegian and Commonwealth Heads of Military Missions houses, in addition to over 800 married quarters and the stadium headquarters itself. Garrison Engineer West on the other hand has to compete with all the military barracks and installations in the city and 200 married quarters.

District new services have topped the hundred mark during the last year, mainly as a by-product of the policy of concentrating the British community in Berlin in the general area of the Olympic Stadium and Spandau. The coming year looks likely to be at least as busy, as further works are already planned or projected to the same end.

Turning to the E. & M. side, many of the capital new works mentioned above have included large-scale heating or electrical problems. Maintenance commitments range from the magnificent indoor Olympic swimming pool, a number of lifts in big blocks of flats, to the maintenance of refrigerators, despite R.E.M.E. Phase II. The mechanical equipment section has had many fascinating jobs to perform. A straight dozing job on a track which runs right on the zonal border brought Russian heads popping up from under every bush and the job ended with an admiring audience of Russian soldiers standing round. Another job was to help install and rectify faults inside a model atomic pile brought out to Berlin for the British pavilion at the Berlin Industries Fair. The figure from Selfridges of Her Majesty on horseback was also erected outside the British Pavilion. The R.B.19 has been found employment, both as a drag line and as a crane, in jobs ranging from excavating the banks of the

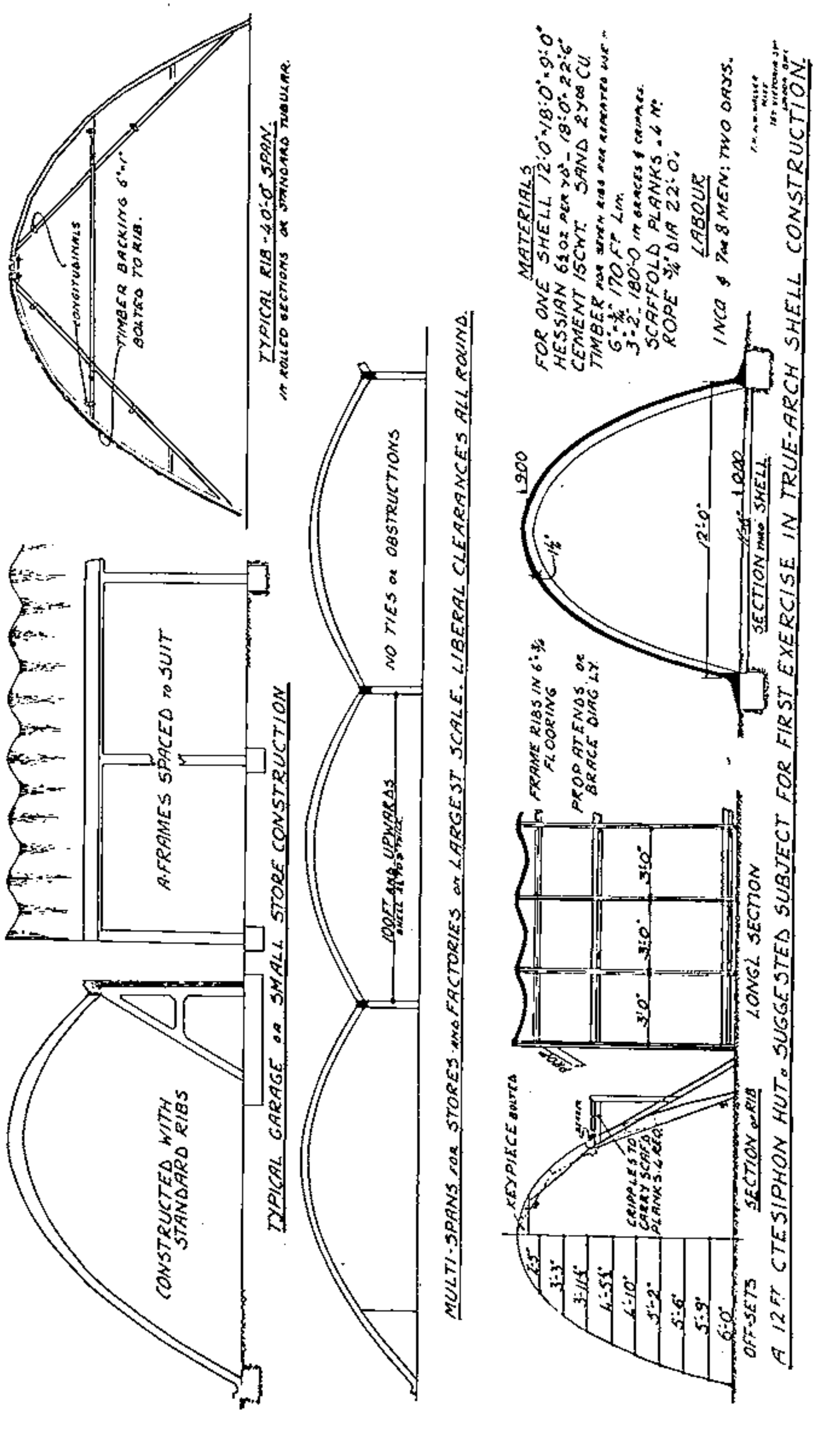
Havel to form a deepwater bankseat for a Class 55/65 raft to off-loading stores from trains in the Stores Depot.

The Stores Depot is divided into two main sections, training-cum-operational and works services including plant spares. From the transportation angle the depot is particularly well served, as, in addition to road and rail facilities, it rejoices in a slipway on to the Havel. Here the training motor boat and cutters are moored and all assault and rafting equipment can be launched ready for towing to the training site. The depot controls a local purchase team which buys those stores needed for direct incorporation in works services jobs and for maintaining depot stocks. For exercises a small advance stores park is formed to handle issues to units.

Two of the main events of the year in Berlin are the Queen's Birthday Parade and the Military Band Display held in the Sommergarten of the Funkturm at the end of the Berlin Industries Fair. Both bring all the elements of the unit into play. The Queen's Birthday requires much work and stores for the preparation of the Maifeld area where Hitler used to review the faithful. At the same time the Field Troop jeeps will form part of the vehicle backdrop to the parade and the Sappers will this year be participating in the parade. The display of massed bands, some of them out from England, is held at night and the provision and manning of floodlights and spot lights is crucial to the success of the show. In addition a large approach ramp down into the area has to be constructed and flanked by four of the decorative poles, erected in Whitehall opposite the Horse Guards, which were sent out specially from England.

Though over one hundred miles the wrong side of the Iron Curtain, the unit feels in no way cut off from the remainder of the Corps in Western Germany. Last autumn we welcomed two Chelsea Pensioners for a short stay in the city. They had come out under the auspices of 26 Field Engineer Regiment and they undoubtedly created a bit of a stir during their tour of East Berlin. During the winter the unit miniature range team reached the finals of the zonal engineer competition and went down to Bad Oeynhausen for the final. In April the Corps Band from Chatham visited us for three days and gave us a most delightful and comprehensive programme, which included two performances to mainly German audiences in concert halls in the heart of the City. In the local competitive field, the unit carried off the minor unit challenge cup at the Berlin Independent Brigade Rifle meeting this spring.

All in all it is fair to say that engineer tasks in Berlin in 1954 make up in variety and scope for any diminution in scale which they may have suffered since the immediate post-war years.



CONSTRUCTED WITH STANDARD RIBS
A-FRAMES SPACED TO SUIT
TYPICAL GARAGE OR SMALL STORE CONSTRUCTION
LONGITUDINALS
TIMBER BACKING 6"x1" BOLTED TO RIB.
TYPICAL RIB - 40'-0" SPAN.
IN ROLLED SECTIONS OR STANDARD TUBULAR.
100FT AND UPWARDS
NO TIES OR OBSTRUCTIONS
MULTI-SPANS FOR STORES AND FACTORIES ON LARGEST SCALE. LIBERAL CLEARANCES ALL ROUND.
MATERIALS
FOR ONE SHELL 12'0"x18'0"x9'0"
HESSIAN 6½ OZ PER YD - 18'0" 22'6"
CEMENT 15CWT. SAND 2YDS CU.
TIMBER
6"x¾" 170 FT LIN.
3"x2" 180'-0 IN BRACES & CRIPPLES.
SCAFFOLD PLANKS 4 No.
ROPE ¾" DIA 22'0".
LABOUR
INCO & 7 OR 8 MEN; TWO DAYS.
KEYPIECE
CRIPPLES TO CARRY SCAFFD PLANKS 4 REQ.
1'5"
3'3"
3'11½"
4'5½"
4'10"
5'2"
5'6"
5'9"
6'0"
OFF-SETS
SECTION OF RIB
FRAME RIBS IN 6"x¾" FLOORING
PROP AT ENDS OR BRACE DIAG'LY
3'0"
3'0"
3'0"
LONGL SECTION
12'0"
SECTION THRO' SHELL
A 12 FT CTESIPHON HUT. SUGGESTED SUBJECT FOR FIRST EXERCISE IN TRUE-ARCH SHELL CONSTRUCTION.

MAKE COVER !

THE CTESIPHON SYSTEM OF CONSTRUCTION

By MAJOR J. H. DE W. WALLER, D.S.O., O.B.E. (late R.E.)

THE following is specifically for junior officers and O.Rs. Not so much for " high ups." It deals with a simple, practical, exercise which, it is hoped, will interest the Sapper and enable him, once in a way, to satisfy a desire which is with us from our earliest years—to build something. This exercise is fun and may lead to . . . but we will see.

In peace and war, the service's appetite for cover, for shelter of all kinds, is insatiable.

What a problem it can become ! Bivvy, camp, workshop, depot, air-shed. To be provided at short notice in all sorts of climates and in the face of unpredictable limitations as to quality and quantity of materials, labour, technical personnel and equipment. What can we do ?

First, look at the cards and see what sort of hand we hold. There is *tentage*, the age-old standby, easily transported, quickly set up and struck, very expensive and canvas getting scarce. Its place is as near the front line as possible and the sooner it can be released and sent forward the better. An emergency shelter. Mobile.

Next we have *steel*, in rolled sections and sheets : the most versatile of all materials and for that very reason sought after for a great variety of purposes : consequently it has an awkward way of getting into short supply. If we can succeed in reducing the demand on steel supplies it will be for the common good. Much the same applies to aluminium.

Cement asbestos comes next. Usually a second choice to steel for cladding ; brittle, tragically allergic to blast ; a poor substitute.

Prefabricated concrete : hard to transport and of limited application.

Timber : seems to have vanished.

A fairish hand admittedly, but with weaknesses. Let us draw another card and hope it will fill a gap.

THE CORRUGATED CONCRETE TRUE-ARCH

Plate I shows a humble little structure, a corrugated concrete Ctesiphon shell of only 12 ft. span, but, small and all as it is, one for which sundry uses can be found. Having proved that a N.C.O. and half a dozen men can pop it up in a couple of days I venture to say that—having nervously removed the forms and given it a gentle push, then kicked it, backed a lorry into it and loaded it with men, *à la* grandstand, and *seen that it is good*—someone will want to have a crack at a thirty-or forty footer ! And why not ? Is there any better training or more useful form of shelter ?

Let us set to work right away.

Preparation

Give the carpenters :—

170 ft. of 6 × $\frac{3}{4}$ in. boards
180 ft. of 3 × 2-in. battens
5 lb. 2-in. nails.

Get them to knock up a set of seven ribs and two pairs of cripples, as shown in plate. These will let us put up in one operation, 18 ft. of shell with 3 ft. corrugations. A goodly wee hut.

Stores Required

Refer to plate.

Labour

One N.C.O., preferably carpenter or plasterer.

Give him this article and let him have a go. It's better training that way.

Two O.Rs. to do rough rendering.

Four O.Rs. to mix and carry the compo.

Don't put on more men, they will only get in each other's way. Now for the two days' work :—

First Day

(*a*) Mark out the founds and open trenches 1 ft. 6 in. wide and not less than one foot deep.

(*b*) Lay battens across trenches, 3 ft. c. to c. and level them through.

(*c*) Set up ribs on the battens, brace and prop ends. While this is going on, fill trenches with compo, gauged six to one, putting in any old bricks or stones available as displacers.

(*d*) Stretch the hessian, previously sewn together into a large sheet to cover the whole roof, over the ribs, pull nice and taut lengthwise of the shell, and fix to end ribs with buttons at 9-in. c. to c., or battens. Pull down very tightly at foot of each rib and fix with button.

A button is a scrap of wood 3 × 3 in. with a nail through the centre—like a drawing pin.

The corrugations will now appear.

(*e*) Lean the cripples, see plate, a pair each side, against ribs and lay the planks on them.

(*f*) Grout the hessian with a two to one grout. A good plan is to mix the grout in a bucket, so that it is thickish, but will pour ; slosh it on with an old tin and spread evenly with brush. The object is to get a good coat on, but even in thickness all over. This even thickness applies to each coat and it is very important to resist the temptation to put on more compo at the top. If the hessian is to be left in place, as is usual, it is well to wet it before grouting. If it is to be stripped for re-use omit this wetting.

(*g*) Stretch the rope over the centre of the central rib, pull down tight and button at foot. If there is time, scud the grout-coat all over to increase thickness and make rendering easier to-morrow. This is not essential.

(*h*) Knock off.

Second Day

The grouted hessian will now be fairly stiff and ready to take the first coat of rendering.

(*a*) Starting at bottom on both sides simultaneously, render all over with compo, gauged three of sand to one cement. Take care not to use too much water, but make a nice workable mix so that the coat will come out between $\frac{1}{2}$ and $\frac{3}{4}$ in.

(*b*) Start again and place a second coat, finish with brush, stroking downwards. The rope will be covered by second coat. When rendering, work well with wooden float and re-float just before the compo goes off so as to close any odd little crazes or imperfections. This additional rubbing up checks contraction—the curse of all rendering—and makes shell impermeable.

(*c*) Collect tools. Return to store. Dismiss.

Third Day

Strike ribs and start on a second hut.

It will all come easier the second time and the result will look better. It will have been learned, for instance, that care must be taken to avoid bulges in the soffit caused by dumping on too much compo on one spot. The use of the tin helps to avoid this. It should be remembered that a bump underneath shows as a hollow to the man on top and he is inclined to add more compo to fill it up ; this makes matters worse, the correct move being to scrape compo out of the hollow so that the bulge may come out.

Another minor point is that the hessian may surge across the rib into the next corrugation as the compo or grout is being placed. This tendency is avoided by placing the material over the rib and working downwards on either side into the corrugation.

Little points such as these become evident with practice, their discovery gives scope for care and watchfulness and ingenuity so desirable in any exercise.

Heavily loading this unreinforced shell, little more than one inch thick, may seem to be " sticking one's neck out," and a few words of explanation as to why this is practicable may be of interest.

It is my belief that since Bessemer made steel cheap and plentiful we have placed too much reliance on the joist, beam and girder. These enclose no space and have a relentless foe in gravity. I feel we should get this great force on our side by making more use of the arched form. Gravity favours the arch and, above all, the true or catenary arch, built to the curve of the hanging chain reversed. Then, just as we stiffen sheets of steel and cement-asbestos by corrugations, we should corrugate the arched shell. Thus with a surprisingly thin sheet of concrete, happy because in compression, we get a grand section modulus, moment of inertia, call it what you will—stability, rigidity—even without any reinforcements. And the true arch, employed 4,000 years ago in Upper Egypt, is still so bang up to date : for, mark you, *it is prestressed.* Naturally prestressed by gravity. All who harken to the back-room boys know what economies derive from pre-stress.

Let us go back to the first year lecture-room for a moment and see what statical justification there is for these views.

The free catenary arch, of uniform thickness, it will be remembered, is evenly compressed : free from bending and free from tension ; the line of stress lies centrally in the section. When eccentric loads are applied, say wind or snow, this line of stress is deflected to one side or the other, just as the chain swings to one side when loaded unevenly. Let us follow its course and note the results.

Stage 1.—The wind, say, sets in and the line moves sideways, increasing compression on this side and reducing it on that, until it reaches our old friend "the middle third," when its effect is doubled on the compression side and reduced to zero on the other.

Stage 2.—As the wind increases further, the line moves still more off centre increasing the respective tension and compression until this wind-derived tension neutralizes the natural compressive prestress due to weight of the shell—gravity. The particles on this side are now setting pretty, not being stressed at all, while on the opposite side they are subjected to still more compression and, being concrete, like it well.

Stage 3.—The wind rises further, tension starts to build up on one side until it reaches the tensile strength of the concrete. We may now look out for the first crack. It will be so fine we cannot see it, but it is there all right and will probably show up as a damp spot on the soffit of the arch after prolonged rain.

Stage 4.—This tension increases with the wind and with it the tendency to leak. We can now introduce reinforcements but there is a much more attractive course open to us—we can use deeper corrugations, increase the lever arm and cut out this tension—all thanks to our ally, gravity.

It may be added in passing that for small spans, forty or fifty feet say, with normal rise/span ratios up to $\frac{1}{2}$, these shells are amply stiff to resist wind pressures ordinarily specified, without tensions arising which call for reinforcements. This is an important matter in the field. On the other hand if abnormal rigidity is demanded—to resist bomb shock or serious earthquake for example—a little steel is highly effective owing to the large lever arm provided by corrugation.

Photo 1.—The Great Arch of Ctesiphon. The ancient Persians built this of Tigris mud. They got the shape right. That is why it has been able to withstand the centuries.

Photo 2.—The Indians build Ctesiphon houses, some with double shell and cavity to ensure insulation. Possible for housing troops at the base ?

Make Cover 1 , 2

Photo 3.—This is a workshop—and store type, from Tanganyika.

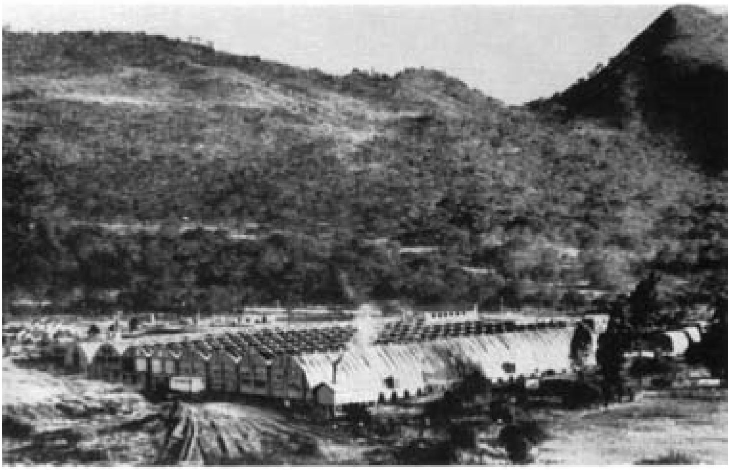


Photo 4.—An example of factory construction built by native labour at Umtali in Southern Rhodesia. A hundred yards square in plan.

Make Cover 3 , 4

This elimination of reinforcements not only lightens the shell, since no cover for steel is required, but it greatly simplifies construction of that simplest of all structures—the arch. And simplicity has handmaidens called speed, efficiency and economy.

Now. What about this forty-footer that has been mentioned ?

In this case 4 ft. wide corrugations are suitable and up to six feet permissible. The sag should average about nine inches.

Typical ribs, for 20 ft. rise, are shown and may be made up in standard scaffold tubes or $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$ in. angles. They make a neat exercise for the welders and will give years and years of service. If any other rise is preferred, hang up a chain or by other means draw out the catenarian curve desired and so obtain the offsets. A set of five ribs will give 16 ft. of shell at each setup.

Here again I advise sewing up the hessian into a sheet to cover the 16-ft. section, and in all hessian sheets arrange that the seams, made tarpaulin fashion, run across the shell. To erect, carry on as before. You will require an extra man each side to act as spreader's mates and this gang—

> one N.C.O., two spreaders, two spreader's mates,
> two wheeling concrete and two mixing—
> total nine men—

should put up the 16 ft. in three days ; the shell will be the same thickness as before—requirements are merely sand, cement, sacking and savvy. This size is successfully used for churches, cinemas, N.A.A.F.Is, canteens, etc.

Table I below gives compressive stress on the concrete for various spans and rise/span proportions. These figures are per inch length per inch thickness of shell. From them the thrusts in foundations are easily computed.

As a general rule the appropriate spacing of the corrugations can be taken as 3 ft. up to 30 ft. span, after which 1:10 of the span is suitable. For depth of corrugation, 6 in. for a 30-ft. span gives good results, increasing to 9 in. for 40 ft., 12 in. for 50 ft. and 14 in. for a 60-ft. span.

TABLE I.—COMPRESSIVE STRESSES AT SPRINGING OF CONCRETE ARCH

Rise/span ratio	Span : feet					
	60	100	150	200	300	700
	Compressive stress : lb. per sq. in.					
1 : 2	51	84	126	168	253	591
1 : 3	47	79	118	157	236	551
1 : 4	50	82	123	165	247	577
1 : 5	54	89	134	179	268	626

Now for the things I have forgotten.

Oh yes !

The rope. The rope is used to make a transverse line of weakness in the shell so that, when the concrete shrinks lengthwise, cracking will take place at the rope. Joints should be spaced not farther than 12 ft. apart in unreinforced shells. A fine hair crack will gradually develop immediately over the rope, but as it is in the crest no water will get in and the little that does is absorbed by the rope. I can't think why this is sometimes called the Irish joint. For really permanent first-class work other forms of joints are preferable, but the rope joint is all right for the purpose under discussion.

The concrete, of course, shrinks transversely also but the arch is free to move up and down—breathe—and so no horizontal jointing is necessary. Out of regard for this latter movement joints between solid partitions and shell should be made in lime mortar.

It will be obvious that many forms, other than the simple arch may be built. The plate shows an open-sided type which, if constructed on 40-ft. or 60-ft. ribs, makes excellent shelter for mechanical transport, stores, etc. There is also shown Ctesiphon in multi-span construction which is suitable for storage on the largest scale. There remains the tied arch, carried on walls or lintels and columns. It raises one nice little point in that in the case of large spans, when the forms are struck, the load comes on the ties which, being long, stretch considerably and there are induced undesirable bendings in the shell. This is easily got over by prestressing the ties when shell is complete, till they take full load, and then remove the formwork.

It will be seen that although I and my colleagues have been designing and building more and more shells in nineteen different countries for over twelve years and progressively increasing the spans and areas covered, there still remains vast opportunities for development. At times there comes to me a vision that one day will be seen a tattoo performed in the shelter of the Army's own 500 ft. clear span Ctesiphon, with a shell no more than three or four inches thick, easily built as a matter of course in a few months by one R.E. unit.

Yes . . . . that is training with a purpose.

A REVIEW OF THE ANALYSIS OF STEEL STRUCTURES BY THE PLASTIC METHOD

By Lieutenant D. S. Green, R.E.

Introduction

THE plastic method of analysis is new and simple. It provides a rational basis for the economical design of structures. This review is intended to present its fundamentals to engineers whose training in the theory of structures has been confined to considerations of stresses within the elastic range. Attention will be given to mild steel only, although it will be apparent that the method can be modified and extended to certain other materials of comparable ductility.

Conventional methods of design require that, when a structure is subjected to its worst combinations of working loads, none of its nominal stresses shall exceed a certain fraction of the yield stress. For two reasons this is not a realistic requirement: firstly, elastic analysis cannot deal with real stresses because such things as the presence of residual stresses, the settlement of supports, and the flexibility of connexions are generally unpredictable; secondly, many structures will be far from unserviceable when their most heavily stressed parts yield. Indeed, the yielding would tend to distribute the increased loads to other less severely stressed parts, and a reserve of strength would be drawn upon which is not even recognized to exist in this concept of failure. Consequently a new criterion of structural failure has been evolved. This is that structures are unserviceable when collapse is imminent. Therefore the design requirement now is that, when a structure is under a certain multiple of the worst combination of loads, it shall not collapse. This multiple is called the load factor.

A structure is said to have collapsed when its deflections are so large that they are no longer restricted by the elasticity of its members. This state is unlikely to lead to complete breakdown because deflections will usually be restricted by work-hardening or by favourable changes in the geometry of the structure, but such a badly deformed structure would be quite useless for most purposes.

This paper will examine the collapse, under steadily increasing load, of two principal types of structure: that in which axial loads predominate will be considered briefly first; that in which bending effects predominate will be investigated at greater length because they are more common in modern framed buildings. The bending moment distribution in two simple beams will be used to illustrate how plastic collapse in bending occurs. Then it will be shown that it would have been possible to obtain the collapse loads for the beams without considering the bending moment distribution in detail, but by applying instead the principle of virtual work, which gives very easy equations to solve—equations much simpler than those that appear in the elastic analysis of indeterminate structures. Three theorems of limit analysis then enable us to extend the method to more complicated examples (such as plane frames) in which the bending moment distribution is not known *a priori*.

The most economical design for a structure must depend on a knowledge of how that structure would fail in service. This information is given by the plastic method of analysis, and not by the elastic one. Consequently it may now be reasonable to use lower factors of safety than before, because they will only have to provide against overloads and errors in workmanship and not so much against ignorance of stresses and collapse modes. It should be noted that complications such as instability, fatigue, brittle fracture and excessive deflections always have to be considered separately. These may well be more important in the new design than in the old, because a lower load factor would permit higher loads and stresses.[1]*

Elastic-Plastic Properties of Mild Steel

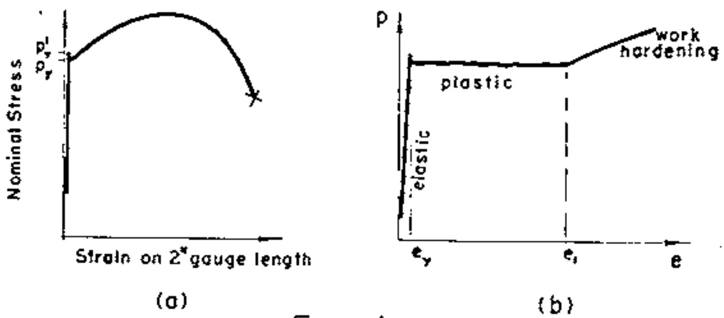


Figure 1

Slow Tensile Test on Mild Steel

If an ordinary slow tensile test were performed on a specimen of mild steel, by imposing strains and measuring corresponding stresses, the familiar graph of Fig. 1 would be obtained. Close inspection of the earlier part of the curve reveals that it may be divided into three sections, elastic, plastic, and work-hardening. In the plastic range the specimen extends under constant stress. So far as we are concerned here, the important fact about this curve is that the plastic range of strain is about ten times as long as the elastic range :—

$$\frac{e_1 - e_y}{e_y} \doteqdot 10$$

* Numbers refer to the bibliography at the end of the paper.

Consequently we shall neglect work-hardening because structures will usually become unserviceable by excessive deformation before work-hardening becomes significant. It will be justifiable to use the curve of Fig. 2 for our calculations, where the material becomes ideally plastic after the yield point has been passed. We shall further assume that the curve for a compression test would be identical with that for a tensile one.

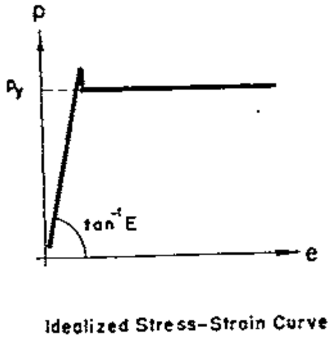


Figure 2

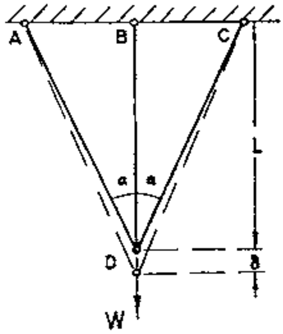


Figure 3

Axially Loaded Members

As a very simple example of a structure with axially loaded members, consider a load W suspended from a rigid beam by three pin-jointed rods of mild steel (Fig. 3). Each rod has a yield stress p_y and a cross-sectional area A. The problem is to find the magnitude of W that will cause indefinitely large deflections of the point D.

Suppose D deflects through a very small distance δ. The strain of DB is greater than the strains of DA and DC. Therefore, as the load is increased, DB will reach the yield point first, and when

$$\frac{\delta}{L} = e_y$$

the load in DB will be $\quad P_{DB} = Ap_y.$

Because this rod is now in the plastic range, it would by itself extend without limit under the load Ap_y. The deflection is, however, still contained by the elasticity of the other two members. As the load is increased still more, the rods DA and DC also yield when their loads are given by

$$P_{DA} = P_{DC} = Ap_y.$$

With the assumption of perfect plasticity, and neglecting work-hardening and geometrical changes, the whole structure is now free to extend. The collapse load is therefore

$$W'' = Ap_y(1 + 2\cos\alpha).$$

Thus if the load factor is n, the working load is

$$W' = \frac{1}{n}Ap_y(1 + 2\cos\alpha).$$

FAILURE OF BEAMS IN PURE BENDING

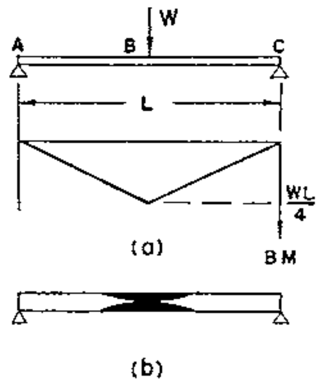


Figure 4

A simply supported beam, subjected to loading at its mid-point, will be most heavily stressed beneath that load (Fig. 4). An investigation of the stresses across this critical section will indicate how collapse occurs. It is permissible to neglect shear stresses if the length of the beam is very much greater than its depth. (The effect of shear stresses will be discussed later.) A rectangular cross-section ($b \times d$) is the simplest to consider first.

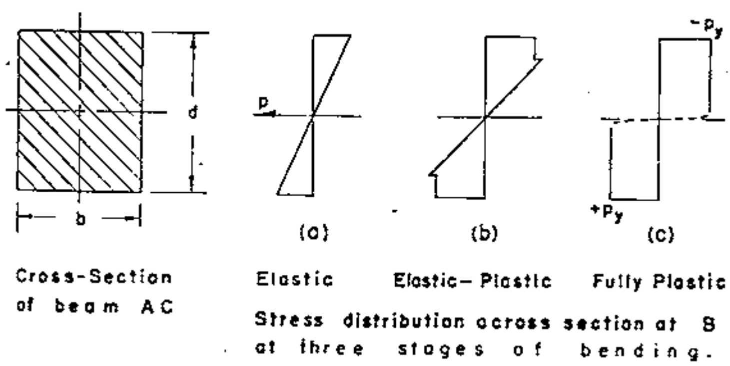


Figure 5

Fig. 5 shows how the stresses across the section behave as the bending moment progressively increases. The usual assumption, that sections which are plane before bending remain so, means that strain is proportional to distance from the neutral axis. Therefore, as the bending moment becomes greater than can be sustained by the section's remaining purely elastic, the outermost fibres yield and extend under constant stress and so allow fibres within the section to reach the yield stress. (Compare Figs. 5b and 2.) In the limit the section becomes entirely plastic and, now that there are no elastic fibres to restrain deformation, the section can bend freely under constant moment. Exactly as though it were a hinge that would rotate only under a given moment, the beam is able to take on an indefinitely great curvature in an infinitely short length. This moment is called the fully plastic moment ; the section at which it occurs is said to be a plastic or yield hinge. M_p is the symbol commonly used to denote a section's fully plastic moment. In the example of Fig. 4, when

$$\frac{WL}{4} = M_p,$$

the beam is free to fold about the plastic hinge at B and fall into the gap. The plastic domain which exists when collapse is imminent has been marked in solid black in Fig. 4b.

From the dimensions of the cross-section and the distribution of stress in the fully plastic state (Fig. 5c), for a rectangular beam bent about its major principal axis,

$$M_p = \tfrac{1}{4}\, p_y b d^2.$$

For other shapes of section, M_p depends on their geometry.

If M_y represents the moment at which yielding of the extreme fibres of a beam first occurs,

$$M_y = \frac{2Ip_y}{d},$$

where I is the second moment of area of the section about its axis of bending, and d is its depth. There are ratios called form factors relating M_p to M_y for standard rolled sections and so obviating the computation of M_p from first principles. If f represents a form factor,

$$f = \frac{M_p}{M_y}.\ *$$

Hence $$M_p = f\,M_y = \frac{2fIp_y}{d}.$$

For rectangular sections

$$f = \frac{\tfrac{1}{4}p_y bd^2}{\tfrac{1}{6}\,p_y bd^2} = 1.5.$$

To achieve this concept of a plastic hinge several idealizations had to be made. If from the same piece of steel a tensile test specimen and a rectangular beam be made, the first can be used to find the yield point and the second can be loaded similarly to the beam of Fig. 4. If in the second case one were to plot central deflection δ

* For standard I sections bent about stronger axis, $f \doteqdot 1.15$. For wide-flanged I sections bent about stronger axis, $1.05 < f < 1.10$. For all I sections bent about the weaker axis, treat the flanges as two rectangles using $f = 1.5$.

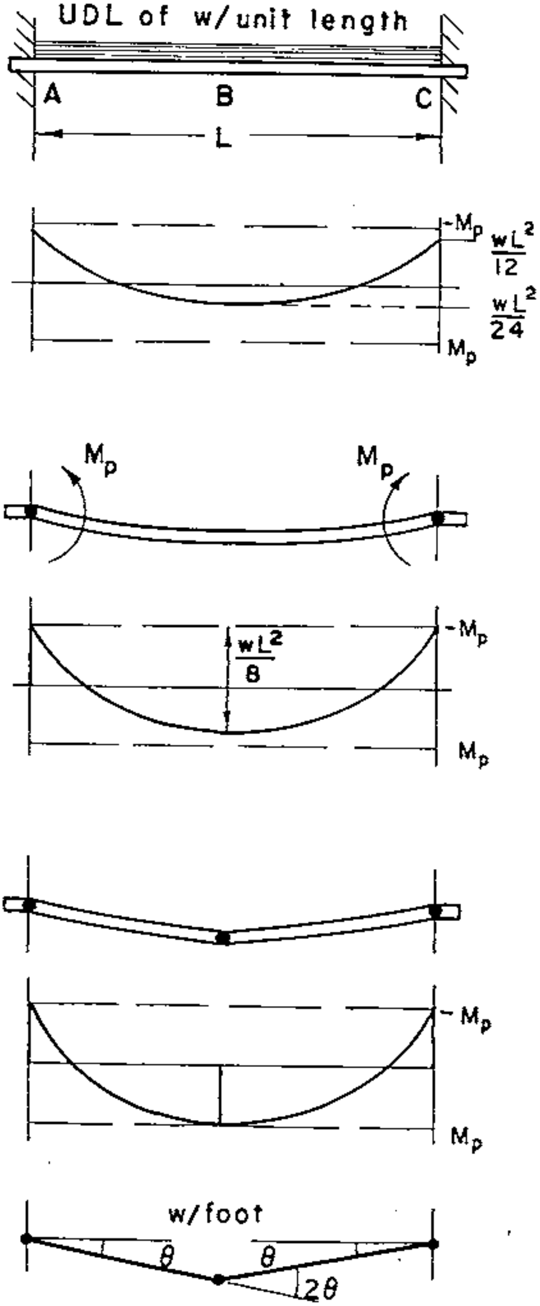


Figure 7

(a)

Bending Moments

Elastic

(b)

Elastic-Plastic

(c)

Collapse

(d)

against load W, the graph of Fig. 6 would be obtained, where M_p and M_y would be calculated from the result of the tensile test. This verifies the practical validity of our notion of plastic collapse.

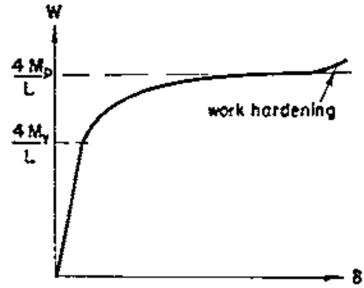


Figure 6

For a second example, let us take a statically indeterminate problem, a uniformly loaded beam with built-in ends (Fig. 7a). This time, as the load is increased, the first sections to become fully plastic are at the ends A and C. When this happens plastic hinges form, but the beam cannot collapse because it is not yet a mechanism. As further increases in load are made the hinges rotate and allow the beam to bend downwards as though it were pinned at the ends but had restraining moments equal to M_p at each pin (Fig. 7b). This process continues until another plastic hinge forms at the next most heavily stressed section, the mid-point (Fig. 7c); that is until

$$\frac{WL^2}{8} = 2M_p.$$

Now a mechanism has formed and deflections become intolerably large (even though in this case the beam is attached to the walls). The beam can be regarded as having collapsed.

The examples have foreshadowed a general principle: collapse of a structure will occur when the fully plastic moment has been reached at sufficient points for a mechanism to form. There is a theorem that states this more precisely, and there is a uniqueness theorem that enables us to tell whether, in estimating the collapse load, we have in fact estimated the correct load. These theorems are vital for collapse analysis and they will be stated in terms sufficiently general for our present purposes.

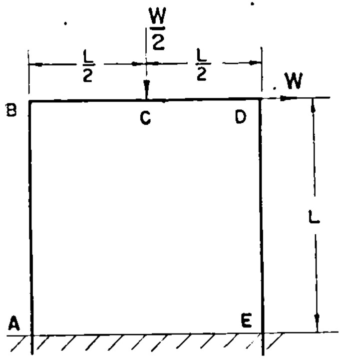
The Static Principle[2]

If for a given loaded structure it is possible to find *any* bending moment distribution* which both satisfies the conditions of equilibrium and nowhere exceeds the fully plastic value, the load will be either less than or equal to the collapse load.

The Uniqueness Principle[3]

If for a certain magnitude of loading on a given structure it is possible to draw a bending moment diagram which satisfies the conditions of equilibrium and is consistent with the presence of

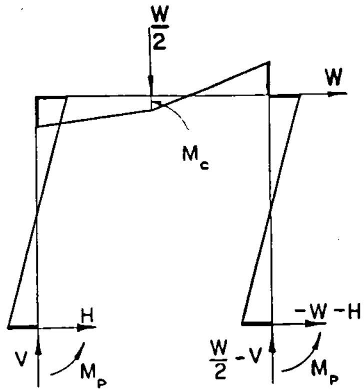
*Although for statically determinate structures only one bending moment distribution is possible, for indeterminate problems an infinity of such distributions can be found.



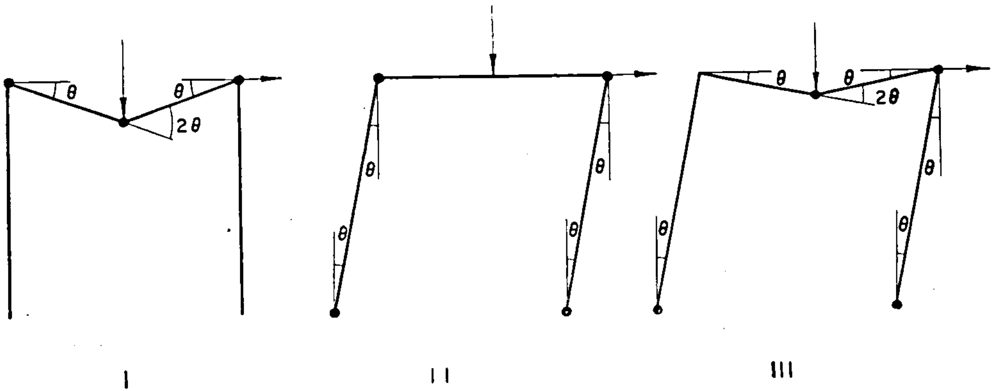
(a)

Figure 8

(c) is the bending moment diagram to check Mechanism II



(c)



(b)

plastic hinges at sufficient sections for the structure to become a mechanism, that load is the collapse load, and it is impossible, at this or any other load, to find any other bending moment distribution also satisfying these conditions.

THE KINEMATIC APPROACH

Happily it is possible to estimate the collapse load of steel structures without having recourse to bending moment diagrams except as a final check. This is fortunate because the method that has just been used for beams, that of seeing how the bending moments develop as the loads increase, is tedious in the extreme when applied to frames.

The kinematic approach[4] depends on two theorems stated below. The essence of the method is to try all possible collapse mechanisms, and to find the loads associated with each by means of the principle of virtual work. The correct one can then be selected by the criterion of the kinematic principle.

The Kinematic Principle[2,5]

Of all the possible collapse mechanisms for a given structure, the actual one is that associated with the smallest load.

The Principle of Virtual Work

The total work done by *any* system of forces in equilibrium, when *any* set of compatible virtual (real or imagined) displacements is imposed on the system, is zero.

By " any set of compatible virtual displacements " is meant any set of displacements compatible with the continuity of the medium on and in which the force system acts. It is necessary to emphasize that these displacements need not be those caused by the force system itself. The theorem is independent of the physical properties of any media on which force systems may be considered to act.

An example, the rigidly jointed portal frame of Fig. 8a, will illustrate this approach. The feet of the frame are rigidly fixed. Identical members are used for the beam and stanchions so that the fully plastic moment M_p is constant throughout the frame. The two loads W and $\frac{1}{2}W$ increase gradually and in constant proportion to each other until a state of collapse is reached. It is required to find the magnitude of W at collapse assuming that the effects of axial and shear forces are negligible.

It is not known *a priori* at which sections the plastic hinges will form, but it is known that the maximum bending moments in frames with straight members and point loads must be at joints and loading points. This is because the bending moment diagram is composed of straight lines. All possible mechanisms meeting this requirement are shown in Fig. 8b. Which is the correct one ?

The virtual displacements are specified by the rotations θ. These will be assumed to be so small that second order effects can be neglected. Now no hinge could develop without the fully plastic moment being attained there, and so application of the principle of virtual work to each mechanism in turn gives :—

$$\text{I} \qquad \frac{W}{2}\frac{L}{2}\,\theta - 4\,M_p\theta = 0 \quad \therefore W = \frac{16M_p}{L}$$

$$\text{II} \qquad WL\theta - 4\,M_p\theta = 0 \quad \therefore W = \frac{4\,M_p}{L}$$

$$\text{III} \qquad \frac{W}{2}\frac{L}{2}\,\theta + WL\theta - 6\,M_p\theta = 0 \quad \therefore W = \frac{24\,M_p}{5L}$$

(*Note*: work done by internal forces at hinges is always negative.) The smallest load associated with these mechanisms is

$$W = \frac{4M_p}{L}.$$

Therefore this is the collapse load and Mechanism II represents the mode of collapse. This result has to be checked by drawing the appropriate bending moment diagram to see if the conditions of the Uniqueness Principle are met (Fig. 8c). The bending moment at C must not be greater than M_p. Equilibrium conditions must be satisfied.

Equilibrium:

Left hand stanchion $\qquad HL = -2M_p \quad \therefore \quad H = -\dfrac{2M_p}{L}$ ......(1)

Right hand stanchion $-(W + H)L = -2M_p \quad \therefore (W + H) = \dfrac{2M_p}{L}$ ......(2)

(1) + (2) $\qquad W = \dfrac{4M_p}{L}$ ✓

Beam $\qquad VL - \dfrac{W}{2}\dfrac{L}{2} = -2M_p \quad \therefore \quad V = -\dfrac{M_p}{L}$ ......(3)

Check M_c : $\qquad M_c = M_p - \dfrac{M_p}{L}\dfrac{L}{2} = \dfrac{M_p}{2} < M_p$ ✓

Uniqueness Principle not contravened.

The simplicity and brevity of this method are striking. An elastic analysis of the same frame, which is thrice redundant, would take much longer and be more liable to arithmetical error. Even for the case of the beam in Fig. 7 it is an advantage to use the virtual work concept. This time the collapse mechanism can only be that of Fig. 7d. The virtual work equation is

$$wL\left(\frac{1}{2}\frac{L}{2}\,\theta\right) - 4M_p\theta = 0 \qquad \therefore \; w = \frac{16M_p}{L}$$

Thus a one-line solution yields the collapse load without any consideration of the bending moment diagram except the intuitive knowledge of where the maxima must be.

No account is taken of elastic deflections in the equations because the principle of virtual work specifies "*any* compatible set of deflections." One therefore takes the simplest set that can be found, however artificial.

Before the kinematic method can be used with confidence, it is necessary to be certain that all possible collapse mechanisms have been tried. It can be shown that *the number of independent mechanisms associated with any loaded frame is equal to the number of independent equations of equilibrium.*[4] Having found this number of mechanisms and ensured that they are independent, it is a simple matter to consider combinations of them. The set of independent mechanisms selected may not be a unique set, but, whichever set is taken, when all its members have been combined in every possible way, it will give all possible collapse mechanisms. For the portal frame of Fig. 8, if the five bending moments, M_A, M_B, M_C, M_D, M_E, are known, the whole stress distribution is determined and the bending moment diagram can be drawn immediately. Hence there are five unknowns, but the frame has three redundancies, so there must be $5 - 3 = 2$ independent equations of equilibrium. Any two of the mechanisms of Fig. 8b may be taken as being independent, and the third as their combination.

Example of Two-storey, Single-bay Plane Frame

The frame shown in Fig. 9a* will be our last example and will demonstrate all the points mentioned so far as well as how a practical frame problem would be tackled. In addition to the floor loads, two side loads simulate wind loads. The stanchions have fully plastic moments of M_p, and the beams of $2M_p$. All joints are rigid. It is required to find the magnitude of W at collapse. (The effects of shear and axial forces will be neglected.)

(*a*) *The Number of Independent Collapse Mechanisms*

The bending moments that are needed to specify completely the stress distribution in the frame are $M_A \ldots M_Q$. (In the case of the beam QM, the parabolic bending moment diagram would be uniquely defined by M_M, M_N, M_Q.)

	Number of unknowns :	14
	Number of redundancies :	6
∴	Number of independent mechanisms :	8

Of these eight mechanisms, four represent isolated rotations of joints. Therefore the number of interesting independent mechanisms is four. These are taken to be Mechanisms I to IV in Fig. 9, although it would be possible to select another set whose members were independent.

* See Folding Plate facing page 390.

Plastic hinges at joints will occur in the way that involves the least plastic work. This has been indicated in the diagrams by placing the hinges a little way from the joints. The most straightforward cases are the top beam to stanchion connexions. Here the hinges will always be in the stanchions because they are weaker sections than the beams.

(b) Application of the Principle of Virtual Work

Mechanism I

$$2WL\theta - M_p 4\theta = 0 \qquad \therefore W = 2\frac{M_p}{L}$$

Mechanism II

$$3WL\theta - M_p 4\theta = 0 \qquad \therefore W = \frac{4}{3}\frac{M_p}{L}$$

Mechanism III

$$5WL\theta - 2M_p 2\theta - M_p 2\theta = 0 \qquad \therefore W = 1.2\frac{M_p}{L}$$

Mechanism IV

$$5W\frac{L}{2}\theta - 2M_p 4\theta = 0 \qquad \therefore W = 3.2\frac{M_p}{L}$$

Now all combinations of these mechanisms have to be tried.

Mechanism V (from I and II)

$$5WL\theta - 8M_p\theta = 0 \qquad \therefore W = 1.6\frac{M_p}{L}$$

Mechanism VI (from I, II, III and IV)

Assuming as a first approximation that the hinge in the lower beam will be at the mid-point,

$$\frac{25}{2}WL\theta - 16M_p\theta = 0 \qquad \therefore W = 1.28\frac{M_p}{L}$$

Mechanism VII (from II and IV)

With the same assumption as for Mechanism VI,

$$\frac{11}{2}WL\theta - 10M_p\theta = 0 \qquad \therefore W = 1.82\frac{M_p}{L}$$

Mechanism VIII (from I and III)

$$7WL\theta - 8M_p\theta = 0 \qquad \therefore W = 1.14\frac{M_p}{L}$$

Mechanism VIII gives the lowest collapse load, but it is feasible that, if the hinge in the lower beam were in its optimum position, the collapse load of VI would be less than this. Let the central hinge of the lower beam be distant x from the left-hand stanchion (Fig. 9b). If ϕ is the small angle of rotation of the central hinge,

$$\phi = \frac{2L}{2L - x}\,\theta.$$

Thus the virtual work done by the uniformly distributed load is $\frac{5}{2}Wx\theta$ and that done at the hinges is $-4M_p\phi$. Introduction of these quantities into the equation for the whole mechanism gives

$$10WL\theta + \frac{5}{2}Wx\theta - 8M_p\theta - 4M_p\phi = 0.$$

Therefore

$$W = \frac{24L - 8x}{20L^2 - 5xL - \frac{5}{2}x^2}M_p.$$

Minimizing W with respect to x:

$$x \doteqdot 0.35L$$

and hence

$$W = 1.18\frac{M_p}{L}$$

This, however, is still greater than the collapse load for Mechanism VIII, which must therefore be the actual collapse mechanism. The true collapse load of the structure is

$$W = 1.14\frac{M_p}{L}.$$

Drawing the bending moment diagram for Mechanism VIII shows that the requirements of the Uniqueness Principle have been met.

In practice it is not necessary to try all possible combinations of mechanisms. Judicious selection will lead to the combination of only those mechanisms that will produce a lower collapse load than each had originally. The scheme is to try to reduce the plastic work done by eliminating hinges. For instance, combination of Mechanisms I and III in the example cancelled the top left-hand stanchion hinge for Mechanism VIII. Skill and intuition often give rapid solutions.

Only rigidly jointed structures have been treated so far. The flexibility characteristics of riveted connexions, which greatly affect stress distributions in frames right up to collapse,[8] in no way alter actual collapse modes and their corresponding loads, provided only that such connexions can develop at least the fully plastic moments of the members to which they are attached. Thus, our analysis has not to be modified to account for the behaviour of connexions when they are strong enough. It is nevertheless clear that in practice the easiest way to achieve this requirement of undiminished fully plastic moment is to weld the connexion. This means that the difficulties inherent in welding have to be overcome, but this can often be done.

Limit Analysis

The Static and Kinematic Principles are even more powerful than has appeared so far. They are the basis of the general theory of limit analysis,[2,9] which is one of the most valuable parts of the theory of plasticity and which facilitates the estimation of approximate failure loads when the discovery of true stress distributions and collapse mechanisms is too laborious. The Static Principle implies that if any statically admissible stress field, nowhere exceeding the yield limit, can be found for a given load on a structure, then that load is a lower bound to the collapse load. In other terms,

$$P_s \leqslant P$$

where P is the actual collapse load, and P_s is the load corresponding to any stress distribution complying with the Static Principle. Furthermore, the Kinematic Principle means that any kinematically admissible mechanism will determine an upper bound to the collapse load. Thus, if P_k is the load corresponding to any such mechanism,

$$P_k \geqslant P.$$

P lies between these two bounds,

$$P_s \leqslant P \leqslant P_k.$$

The degree of approximation to P achieved is the difference between P_s and P_k. The Uniqueness Principle states that when

$$P_s = P = P_k$$

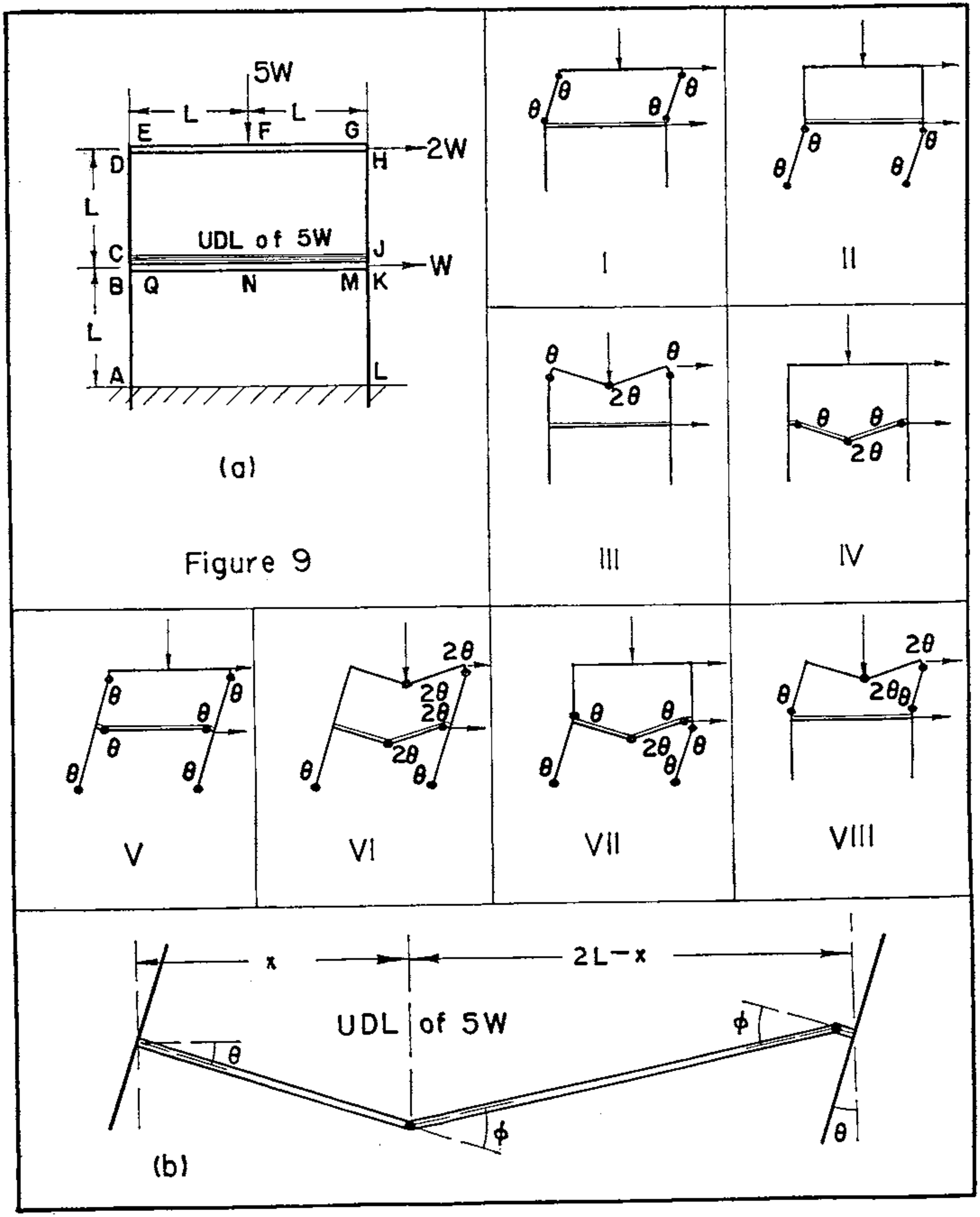
P is the actual collapse load. The art of limit analysis is to conjecture permissible stress and flow fields which give upper and lower bounds as close together as desired.

Cyclic Loading

It is not sufficient to consider only monotonically increasing static loads which bear constant ratios to each other. A set of loads, which never exceeds its collapse magnitude as computed in the way described above, may even so cause collapse if the loads vary cyclically. There are two ways in which this may come about.

The first is known as *alternating plasticity*.[7] It corresponds to the bending of a bar to and fro until it breaks. This type of failure seldom appears. In real buildings collapse is usually caused by one or two overloads, or else by very many stress reversals such as cause fatigue failures in railway bridges. The intermediate, fairly large, number required for the alternating plasticity type of failure is rare in practice.

The second way is called *incremental collapse*.[5] When a structure is loaded beyond the elastic range parts of it will yield. Now, if some of the loads are removed, there will be a redistribution of stresses ; when they are replaced the new stress distribution will not be that which existed before the loads were taken off, and the deflections will also be different. This is because the principle of superposition holds only when there is a linear relation between load and deflection. If as the loading cycle is repeated a few times the deflections become greater and greater, the structure will collapse even though a mechanism has never been present. If, on the contrary, such



5W
L
L
E
F
G
2W
D
H
L
UDL of 5W
C
J
W
B
Q
N
M
K
L
A
L
(a)
I
II
III
IV
V
VI
VII
VIII
x
2L−x
UDL of 5W
θ
φ
(b)

Figure 9

additional deflections decrease as each cycle is performed until the loading cycles give rise to only such changes in the stresses as can be accommodated elastically, then the structure is said to shake down and it is safe. There is a theorem which helps to ascertain whether a structure will shake down in any given set of circumstances. It is a special case of a more general one.

Shake-down Theorem[5]

If any particular system of residual moments exists which would enable all further variations of the applied loads between their prescribed limits to be supported in a purely elastic manner, the structure will shake down, although the actual system of residual moments existing in the structure when it has shaken down will not necessarily be the particular system which has been found.

Step-by-step elasto-plastic calculations for some cyclically-loaded structures have been done. These show that the magnitudes of the upper limits of loads that would produce incremental collapse usually lie between 85 and 100 per cent of the ordinary collapse loads for progressively increasing loads. In spite of this, buildings are more liable to fail in their normal modes under the corresponding collapse load than they are to collapse incrementally under the reduced load then necessary. This is because single excessive overloads are more probable than successions of overloads whose magnitudes lie part-way between the regulation working loads and the actual calculated collapse for slow loading. Hence if the load factor used in design is not less than say 1.5, it may be possible to assume that the protection against incremental collapse is greater even than that against single overloading. Except for unusual structural configurations in which there has been no experience, it may therefore be unnecessary to compute the load limits that would just cause incremental collapse.

Axial and Shear Forces

The effects of axial and shear forces on members whose strength depends on their resistance to bending have so far been neglected. Often this neglect is insignificant but it must always be justified.

In most beams shear forces affect the fully plastic moment only slightly. This can be established by using the theory of perfect plasticity,[9] which is the counterpart of the classical theory of elasticity. The description of such a method is beyond the scope of this review. It will be remembered, however, that the distribution of shear stress across a rectangular beam section in the elastic range is parabolic, being at its maximum at the neutral axis and diminishing to zero at the extreme fibres. Thus, when bending moment is present as well as shear, the beam will yield in three domains: two outer ones in which bending stresses predominate, and another centred on the neutral axis in which yielding is mainly due to shear stresses. When the boundaries of these regions meet, a new sort of plastic hinge will have formed with less bending moment than could have been applied if no shear stresses were there.

Graphs have been drawn to show the percentage reduction of fully plastic moment by shear forces. They may be found by referring to the papers listed in the references.[8] In the case of standard I-beams, the effect of shear is negligible provided

$$\frac{M}{F} > 4d$$

where M and F are the bending moment and shear forces at the section considered, and d is the depth of the beam.

Leaving aside the question of stability, the result of axial forces is again to diminish the fully plastic moment. A beam of rectangular cross-section will once more illustrate this most easily (Fig. 10).

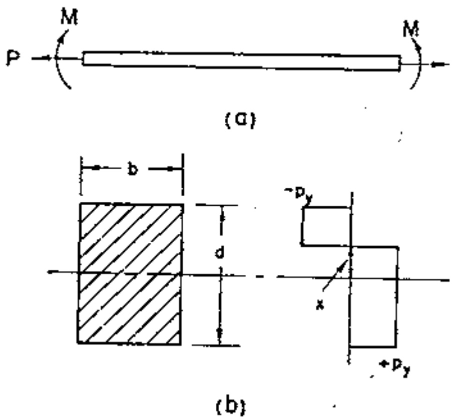


Fig. 10

Suppose it to be subjected to end moments M and axial loads P. In the limit, the stress distribution will be that of Fig. 10b. Equilibrium conditions show that

$$P = 2bxp_y$$

and

$$M = b\left(\frac{d}{2} - x\right)\left(\frac{d}{2} + x\right)p_y$$

$$= \tfrac{1}{4}p_y bd^2\left(1 - \frac{4x^2}{d^2}\right)$$

Now if P_p represents the failure load in pure tension, and M_p the fully plastic moment in pure bending, then

$$P_p = bdp_y$$

Therefore $\dfrac{P}{P_p} = \dfrac{2x}{d}$

Similarly $M_p = \frac{1}{4}bd^2p_y$

Therefore $\dfrac{M}{M_p} = \left(1 - \dfrac{4x^2}{d^2}\right)$

Whence $\dfrac{M}{M_p} = 1 - \left(\dfrac{P}{P_p}\right)^2$

This interaction relation is parabolic. It indicates that if $\dfrac{P}{P_p} = \dfrac{1}{5}$, the fully plastic moment is reduced by only 4 per cent.

Stability

When a frame has been analysed, by whatever method, its overall stability and its liability to local buckling have to be examined. At best this is an uncertain procedure. In the ordinary elastic analysis of columns a formula is applied which is based on the greatest allowable stress in the limiting case of symmetrical single curvature. Several different such formulae are in common use and they all give different results. This method is hallowed by age and is used with confidence because buildings analysed in this way before erection have not failed in service. Nevertheless the method depends for its success not on its accuracy but on its safety factor. Until the Steel Structures Research Committee published its reports in the 'thirties,[6] it was not known what really happened in the stanchions of steel framed buildings. The complexity of the analysis the Committee presented and the number of variables it introduced show that it is practically impossible to predict stanchion stresses.

In changing to our new concept of structural failure, our greatest difficulty is here. How will the stanchions actually behave ? The old stress formulae are now invalid ; they do not relate to collapse. Unfortunately the answer is in a makeshift, though no more of a makeshift than the orthodox design method. In fact there is yet no adequate theory of the behaviour of stanchions in steel frames that is readily adaptable to the requirements of practical analysis.

The procedure for the analysis of a frame, taking into account stability, will now be outlined. Firstly, assume that the fully plastic moments are unimpaired by axial forces (shear is usually unimportant anyway) and obtain an estimate of the collapse load in the way described earlier in the paper. Secondly, find the axial forces that would then be present and discover whether they are great enough to affect the fully plastic moment seriously. If they are, correct the moments and carry out the calculations again. This correction must be repeated until the error is too small to matter, although usually one repetition will be sufficient. Finally, the possibility of instability has to be contemplated. Columns having slenderness ratios less than eighty will normally fail by the fully plastic moment being reached before they become laterally unstable. In other cases, columns must be made so stiff that they will not fail by buckling. This is necessary because the major advantage of the plastic collapse method is that it shows the way the frame would collapse, and the designer can use this information to help him achieve an economical structure. Only when he knows the collapse mode can he approach what must be his objective: the simultaneous collapse of all the members of the structure when the working loads are increased by their load factors.[13]

Development of the Collapse Theory

Most of the theory of plastic collapse has been developed since the 1939–45 war. Although some beginnings had been made in Germany before this time, the last decade has seen the almost phenomenal growth of this science.

The theorems quoted in this paper and the general method of attack have been formulated principally by Baker, Horne and Neal at Cambridge University, Hill at Bristol University, and Greenberg, Prager and Symonds at Brown University, Providence, U.S.A. The most useful publications by these and some others are set out in the bibliography. It is hoped that this list will be of service, for no book has yet been published which explains the plastic collapse method in detail.

Whilst the foundations of the mathematical theory of plasticity have now been laid,[9,10] much investigation is going on to extend it to materials other than mild steel, which is almost the mathematical ideal. Reinforced concrete and light alloys are particular examples. The problem of collapse under intense blast loading is being treated theoretically and experimentally at Brown University: Symonds and Lee are leading the work; the author is at present engaged on this topic there.

Conclusions

The plastic collapse concept leads to a quick and realistic method of structural analysis, and, because the true mode of collapse of a structure can be found, it usually gives the most economical approach to design. It is strictly applicable only to materials with well-defined yield points and long plastic ranges, but it can be modified for use with others. Welded connexions ensure that no strength is lost. This accounts for the fact that sheds designed with plastic collapse in mind often have long welded arches rather than conventional riveted roof-trusses, an example of which has already been described in a previous contribution to the *Journal* by Major B. S. Jarvis, R.E.[11] Welding, of course, has its own problems of technique and brittleness, and site welding is especially hazardous.

Although the new design yields lighter and cheaper building frames, there is much conservatism to be overcome in both the contracting industry and the consulting profession. Such reaction is stronger in the United States than in Great Britain. It is wise to be neither over-enthusiastic nor too sceptical. In spite of the method's speed and directness, it must be remembered that much empirical experience is incorporated in existing design codes and that this cannot be lightheartedly discarded. The current code of practice[12] permits the use of plastic analysis but imposes a load factor of 2, which is perhaps unnecessarily high and does not take advantage of the weight-saving potentialities of the method. In military construction there is no such restriction on load factors, and it is important to practise economy because of war-time scarcities. In these circumstances the plastic method is highly commendable.

Acknowledgement

The author wishes to acknowledge his debt to Professor P. S. Symonds, Professor H. G. Hopkins and Dr. J. D. Foulkes, all of Brown University, Providence, U.S.A. for their valuable help, suggestions and corrections.

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THE REGIMENTAL SECOND-IN-COMMAND IN PEACE

By LIEUT.-COLONEL H. G. W. HAMILTON, M.B.E., R.E.

THE job of the regimental second-in-command is full of variety and can be extremely interesting. As the regimental organization is comparatively new, it may be of interest, especially to those officers who are about to take up this appointment, to see what he does and how he occupies his time in peace. Since I have personal experience of the divisional regiment in peace, the bias will be towards the duties of the second-in-command of the Field Engineer Regiment, but most remarks apply equally to all types of regiment.

THE POSITION OF THE SECOND-IN-COMMAND

Like all jobs of deputy commander the second-in-command is in a difficult position. He has no immediate command, and he is not and should not be the link through whom the C.O. gives his orders to his squadron commanders. That is the adjutant's job when written orders are concerned. Neither should he become involved in disicipline and personnel matters, other than welfare, except perhaps in the case of officers. That again is the adjutant's concern. However he must be sufficiently in the confidence of the squadron commanders and understand their difficulties and problems, and more particularly the amount of work the individual squadron commander has on his plate, to enable him to represent their feelings to the C.O. should the occasion arise. At the same time he must be in a position to expect and get unqualified co-operation from squadron commanders on often unpalatable regimental chores ; this may be particularly difficult when dealing with the (otherwise usually first-class) squadron commander who still likes to consider his squadron as an independent command and who looks on the Regimental H.Q., and the whole regimental organization as an unnecessary evil.

For these reasons the task of the second-in-command will be much easier if he has recently had experience in commanding a squadron.

ADMINISTRATION

One's first reaction on being appointed second-in-command is to think that it is wholly an administrative job. So it can be and one has considerable administrative responsibilities—but there are many other facets.

The primary task as the name implies is to be *second-in-command* and that means he must be able to take over command at a moment's notice. If he becomes a super administrator, poring over the P.R.I. accounts, barrack damages and the like all day, he will soon lose touch with the command side of the regiment.

How can the unfortunate second-in-command unburden himself of this load and yet be answerable to the C.O. for the administrative efficiency of the regiment as a whole? A lot will of course depend on the system within the regiment and to what extent squadrons are self administering, but under peace conditions, particularly where the regiment occupies a large barracks, most administration will be centralized and of course it is the regimental quartermaster, another comparative newcomer, who will bear the brunt of all this.

To avoid getting the C.O. burdened with masses of small administrative detail and having to give the Q.M., and other officers concerned with administrative matters, decisions on day to day problems, the second-in-command should act as the main link between the Q.M. and the C.O. in the same way that the A.A. and Q.M.G. of a division links the heads of services, C.R.A.O.C., C.R.E.M.E., etc., with the divisional commander, whilst these commanders still retain right of access.

Training

Where the second-in-command can really help the C.O. is over training, and this I consider to be his most important function, particularly over officer training. M.E., Vol. II, para 62, places on the C.O's. shoulders a large task and it should be the task of the second-in-command to organize all officer training on a regimental basis for him. He should also organize the centralized senior N.C.O. training and E.E.W.T.S.

Regimental Exercises and Training Camps

Where else can he help with training? Most units make one of the liaison officers at regimental H.Q. into the training officer, but this officer in conjunction with the adjutant, is occupied with the numerous details of courses, allocation of stores, ranges, classrooms and the like, and probably for running the regimental cadre classes.

It is with the organization of regimental schemes, exercises, bridging camps and watermanship courses that the second-in-command should concern himself. Most of the organization for these latter events concerns the administrative side, with the detailed programme of training, once the allocation of facilities has been made and a directive issued, being rightly left to the squadron commanders.

A regimental exercise, be it a bridging gallop or demolition exercise, involves a vast amount of detailed planning and preparation. Training rights have to be arranged, equipment reserved, rations and P.O.L. arranged, tentage obtained and extra maps and photos demanded in good time, to mention but a few subjects. In addition, if the exercise is to be a realistic success, other units have to be invited to take part.

It is with the organization of the latter that the second-in-command can most usefully play his part since he is senior enough to talk to the C.Os. of battalions and heads of services, he should anyway be known to them, and he will also have the confidence and ear of the staff of his formation to help him. Finally when all is organized it is the job of the second-in-command to write the exercise and issue the instructions on behalf of the C.O.

Running Exercises

Here I might digress. In a regimental exercise, the H.Q. staff seldom get full value out of it since they are involved with its preparation and know what is going to happen and where. In addition, if the exercise is a large and ambitious one, they become involved with the administration and control of a number of additional units such as police, R.E.M.E., bridge company and even an infantry battalion or a mobile bath unit.

If, however, the second-in-command can set up and run a small control H.Q., apart from regimental H.Q., all these disadvantages will be eliminated. He will of course require a directive from the C.O. regarding the scope of the exercise, the area in which the exercise is to take part, and generally what the C.O. wants taught. Thereafter he should be left to work on his own with perhaps one of the H.Q. subalterns allotted to help him. If an infantry battalion is co-operating they might lend a senior captain or a major to assist during the exercise. All exercise planning should of course be Exercise Secret.

The Control H.Q. will require additional wireless, but that can usually be arranged and the control H.Q. should represent, for example, brigade or divisional H.Q. and the C.R.E., C.C.R.E. or group commander, depending on the unit being exercised. In addition it can usefully control the enemy if there is one. This method ensures that regimental H.Q. can concentrate on their normal task, that rearward communications are practised and that the I.O. is able to function properly and advise his C.O. without "hindsight."

I am of course assuming that in the case of divisional engineers it is peace time and the separate establishment for the C.R.E. has not been implemented ; the A.C.I. which lays down that it must be implemented for exercises is of course unworkable since the extra personnel and wireless and vehicles involved are never available. However the system described is equally applicable to Corps and Army engineers.

P.R.I. Account

But to return to the administrative side and its problem of the P.R.I. account. Some units may have a junior officer detailed to run the account under the supervision of the second-in-command ; if one can be spared this is a good idea. Others in England may be fortunate enough to have a retired officer. A regimental P.R.I. nowadays is a very large account and involves numerous sub-accounts and many entries. It may even be advisable to run a central bank for squadron P.R.I. and this makes the second-in-command's task here larger still. To keep the account correctly and neatly with proper debtor and creditor books, property ledgers and receipt and payment voucher files, involves the account holder in many tedious hours of detailed work. This is purely clerical work which can be done by any neat handed and reasonably intelligent clerk. The army regulation that the accounts must be kept in the hand of the account holder means that an experienced, comparatively well paid and highly trained officer is tied down to routine clerical work when he should be using his talents to better advantage. However, if the C.O. can be persuaded to overlook the regulation and let his second-in-command employ a clerk to make the entries and keep the books, whilst he holds the cash and cheque book, time can be saved.

The second-in-command can not be divorced from the P.R.I. account as through it he controls, on behalf of the C.O., so much of the welfare of the regiment which is certainly one of his jobs. He will have a great interest in the unit N.A.A.F.I. and frequent visits and good liaison with the manageress will pay great dividends.

Messing and Welfare

With regard to messing, there will of course be a regimental messing officer, who may or may not be the unit quartermaster, though the latter is generally responsible for the supply of rations, but the second-in-command will be involved with extra purchases through the P.R.I. and should certainly visit the kitchens and meals at least once per week. He should also attend the regimental messing committee meetings from time to time to ensure they are properly conducted.

Returning to welfare, the second-in-command will generally run the monthly amenities meeting and supervise the running of regimental functions which will probably be best organized in detail by each of the squadrons in turn. It is invariably better to make one squadron completely responsible for a function than to try and run it on a regimental basis, as the squadron command organization can then be used.

The second-in-command should also attend meetings of the corporals club from time to time to see where he can help them and to check that they are being properly run. Sports and games will usually only come into his province as the holder of the purse-strings, but he will have to ensure that the equipment bought from P.R.I. funds for the regiment is properly looked after and accounted for.

Miscellaneous Functions

There are of course many other jobs over which the second-in-command should, on behalf of the C.O., take a supervisory if not a detailed interest. One of these is works services ; the quartermaster naturally deals with day-to-day repairs and liaises with the clerk of works and the garrison engineer, but it is often necessary for the larger guns of the second-in-command to be brought to bear on the G.E. or D.C.R.E. to get things done. Another task is deciding priorities on works orders given to the Field Park Squadron, whilst a further one is co-ordinating any troop trials given to the regiment. Added interest can often be gained from pig farming and general farming. Pig farming especially in B.A.O.R. is a most profitable concern and its supervision generally falls on the second-in-command, but there is something eminently satisfying about pig keeping and to visit them is always a good relaxation from the cares of office.

The Messes

Another task which best falls to the second-in-command is that of P.M.C. of the officers mess. If there is a " living-in " major it is perhaps better that he should do it, but that is seldom the case nowadays.

There are many advantages in his being P.M.C., particularly in a divisional regiment where the squadrons are for ever going off on squadron or brigade exercises. The second-in-command being close to the C.O. in all matters can more easily interpret the latter's wishes in terms of the mess. He knows better who should be guests and invited to mess functions, and being the senior major and having no squadron axe to grind he is in a better position to impose mess rules and standards on all the officers in the mess.

Some units make the second-in-command the officer in charge of the sergeants' mess. I don't think he can run both the officers' and sergeants' messes, particularly as the latter task involves him in daily cash transactions which tend to take up considerable time, so it will be a case of one or the other. Whichever way is decided on he will still maintain a general supervisory interest in both messes and will anyway see the audit proceedings, as all audit proceedings, not only those of the messes, but of squadron P.R.I. accounts and others should be processed through him to the C.O.

Operational Planning

One task which I have not yet mentioned is that of operational planning. This of course does not concern units in England except in war, but in B.A.O.R. particularly it is one which occupies a considerable portion of the second-in-command's time since he has to keep the "top secret" files and register, and answer and even type the correspondence. Since senior commanders are always changing and have different ideas, and the availability of units alters with the cold war situation, so do the detailed plans change with annoying frequency.

Summary of Peace-time Functions

A summarized list of peace-time functions of the second-in-command is as follows :—

1. Operational planning (in certain commands only).
2. Officer and Senior N.C.O. training.
3. Organization of regimental training camps.
4. Preparation of regimental exercises and E.E.W.T.S.
5. Running P.R.I. account and central bank.
6. Welfare and amenities.
7. General supervision of all centralized administration, including, *inter alia*, central vehicle inspections, works services.
8. Supervision of regimental messing.
9. Supervision of corporals' club.
10. P.M.C. officers' mess and/or officer i/c sergeants' mess.
11. Audits.
12. Allocation of priorities to works orders on Field Park Squadron.
13. Co-ordination of troop trials.

Conclusion

It will be seen that the second-in-command of a regiment has in peace-time a formidable task if he is to relieve the C.O. of a lot of detailed work and planning. He can only achieve this by good organization and decentralization. It should, however, be his aim in conjunction with the adjutant to ensure that the minimum of paper has to be seen and dealt with by the C.O., and that the latter is not involved in dealing with numbers of people over trivial matters. By doing this the second-in-command will not only allow the C.O. to get out and about and exercise his command personally, but at the same time he will be so fully in the C.O's. mind that he will be able to take over from him at immediate notice. He should, of course, ensure that he is well known throughout his formation and he should be given every opportunity for taking command for periods, particularly during exercises. In war-time his duties will be much less onerous and his employment and usefulness will depend on the type of warfare existing in the theatre at the time.

PRECAST, PRESTRESSED WORKSHOP

(Details supplied by the Cement and Concrete Association, 52 Grosvenor Gardens, London, S.W.1)

THE new workshop at the Bermondsey premises of the Liverpool Artificial Stone Company Limited makes use both of units cast from standard moulds and of prestressing in its construction. The precast units used for this building are designed to allow for considerable flexibility in arrangement.

The workshop is 75 ft. long by 45 ft. wide. Its frame consists of precast, prestressed concrete trusses supported on columns at 15-ft. centres. Precast, prestressed concrete purlins carry the asbestos cement roofing. The Gifford-Udall-C.C.L. prestressing system was used in both the trusses and the purlins.

The 45-ft. trusses are each made up of fifteen precast units. Some of the units were cast as separate triangles of different sizes, each including a section of the bottom boom, an upright and a raker. The top boom was precast in short, straight lengths which extend from one upright to the next. The centre upright was also precast as a separate unit.

Caulked mortar joints were made between all the units, which were then stressed together with a cable passing through a duct in the bottom boom and anchored in precast end blocks.

The precast purlins, which have a " fish-bellied " profile, were post-tensioned with wires passing along a groove formed in the bottom of the web. After stressing was completed the groove was filled with cement mortar.

The supporting columns for this workshop were of precast, reinforced concrete. In situ reinforced or prestressed concrete columns can, however, also be used with these trusses, or they can be built on to brick piers or any other suitable form of support.

The standard units can be combined to cover any span from 16 ft. to 45 ft. For shorter spans than 45 ft. the same profile of the truss is maintained, but the length of the end blocks and the height of the centre upright are varied, and certain of the larger triangular units can be omitted. The trusses are designed to carry asbestos cement sheets or wood-wool slabs.

Successful tests have been carried out on two of the trusses, which failed at exactly the calculated ultimate load of seventeen tons for each truss.

The cost of the complete framework for this building was approximately 3s. per sq. ft. of floor covered.

The precast units are manufactured by the Liverpool Artificial Stone Company Limited, who also constructed the workshop. The consulting engineer was E. W. H. Gifford, B.Sc., A.M.I.C.E.

Photo 1.—Roof trusses and purlins in position.

Photo 2.—End anchorage block of a roof truss.

Precast,Prestressed Workshop 1 , 2

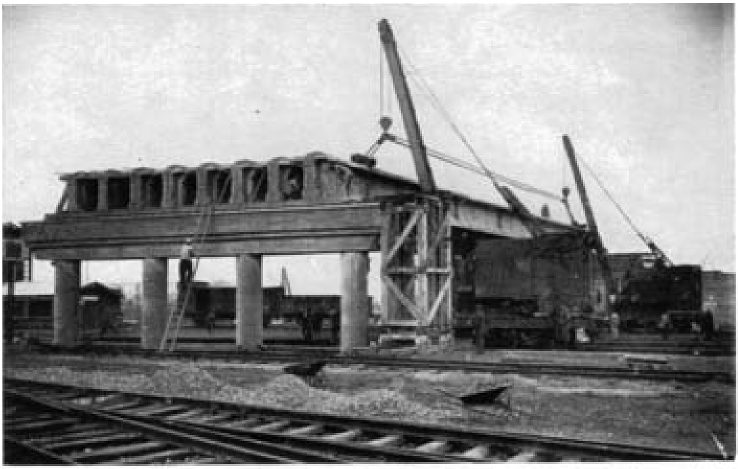

Figure 1.—A road-over-railway bridge at Lille under construction, showing the characteristic bottom flanges of the beams.

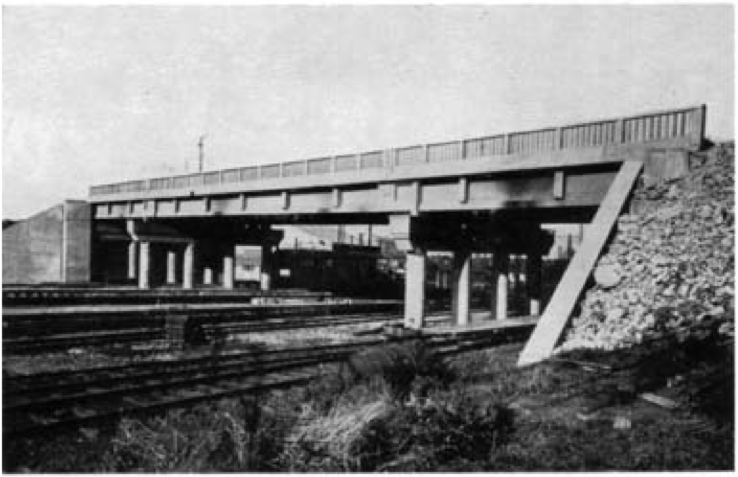

Figure 2.—Lille bridge, completed, showing tell-tale ribs concealing transverse pre-stressing anchorages.

Prestressed Concerete and the field Engineer 1 , 2

PRESTRESSED CONCRETE AND THE FIELD ENGINEER

By Major D. J. O. FitzGerald, D.S.O., R.E.

SYNOPSIS

PRESTRESSED concrete has now been a recognized and widely used structural technique for twenty-six years, and plays a part in countless structures. In particular, a large number of road and rail bridges in north-west Europe are of prestressed construction. The technique has military applications to equipment bridging, prefabricated underground shelter construction as well as to hutting and shedding. It shares with precast concrete the advantage that fabrication can take place in an overseas theatre from materials available on the spot, thus saving transport, and has the further advantage of a saving of up to 30 per cent in cement and 60 per cent in steel on orthodox reinforced concrete.

Concrete is a widely used material in most parts of the world, and there are few theatres where it would not pay an immense dividend to develop the use of concrete in general and prestressed concrete in particular to the utmost limit.

The field engineer must have a practical knowledge of prestressed concrete in order to fulfil such tasks as the classification of bridges, the demolition of bridges and other prestressed structures, the erection of prestressed equipment bridges and of simple cut-and-cover shelters. He must also be able to set up and run a factory for the prefabrication of reinforced concrete and prestressed elements.

Some points are made on the recognition of prestressed bridges, promising points of attack in demolition, and methods of assessing classification. Some limitations of the system are remarked upon.

INTRODUCTION

It is now twenty-six years since the first prestressed concrete structures were erected in Germany and France. By 1939 the method had become firmly established on the Continent, but it took a sustained effort of publicity combined with the acute post-war shortage of steel to recommend the system in the United Kingdom. The "teething" stage is now past, even here, and the technique of prestressed concrete can be said to have taken its place with reinforced concrete and structural steel as part of the stock-in-trade of the non-specialist civil engineer.

The advent of this new structural technique has not passed unnoticed in Royal Engineer circles. Between 1946 and the present moment seven articles on the system have appeard in the *R.E. Journal*. These have dealt mainly with specific applications of prestress to such items as railway sleepers and water containing structures. Instruction in the subject has long been included in the curriculum of the Civil Engineering School at the S.M.E. and many officers will therefore have an adequate knowledge of its principles. Nevertheless it may be valuable to discuss prestressed concrete from the viewpoint of the military engineer. The writer is not, and never has been concerned officially with War Office Engineer policy, so that the ideas which follow are entirely his own, based on his own military experience, and a certain amount of practice in the design and construction of prestressed concrete structures.

Economy in Material

The property of prestressed concrete which will undoubtedly be most interesting to the military engineer is the saving which it affords in the constituents of ferro-concrete. We are constantly searching for means of reducing calls on military transport, and reinforced concrete, of which most, if not all, of the ingredients are locally available in most potential theatres of war, is one structural material which will be used wherever possible. Apart from the enormous quantities of concrete which will be required for airfield construction and road repair and improvement, it will no doubt be found advantageous to set up factories to pre-cast concrete elements for prefabricated hutting and shedding, thus avoiding having to ship its steel equivalent from the home base. A significant further saving can be made in material by prestressing such elements, and it is estimated that by this means, over-all steel consumption could be cut by 60 per cent and cement by 40 per cent.

The problem of releasing equipment bridging erected by forward troops, which was an important one in the last war, will arise again in the next. Whether or not type designs are prepared beforehand, no chief engineer will be able to afford to ignore the possibilities of prestressed concrete in this field. Prefabricated members for stock spans, precast box sections strung together and stressed *in situ* for medium spans, and more elaborate long span bridges will be manufactured in overseas theatres and erected by non-specialist engineer troops.

The introduction of new and more accurate long-range technical weapons, such as guided missiles, whether or not they incorporate nuclear warheads, will renew the demand on the R.E. to construct underground shelters for such vital installations as signals relay stations and headquarters' operations rooms. The prefabrication in the theatre itself of such structures to type designs is a clear necessity : less obvious, perhaps, is the possibility of prestress *in situ* to the linings of such structures to make them waterproof, thus avoiding the necessity for elaborate drainage in waterlogged ground. The production of such designs, incorporating flat jacks, could provide an interesting exercise for the ingenuity of M.E.X.E.

WAYS AND MEANS

If we are to benefit from this invention, and profit to the full by the opportunities it affords, we need most of all to adopt a new attitude of mind towards concrete as a material. The preparation in peace-time of type designs presents no difficulty, and can safely be left to those whose business it is to produce them. (It may surprise some people to know that design in prestressed concrete is easier, quicker and demands fewer drawings than its equivalent in reinforced concrete.) The whole value of such backroom labours will have been lost if the engineer troops in the field remain incapable of mixing high-strength concrete, and *mixing it consistently*.

One does not want to make too much of a fetish of this. The writer's experience leads him to the conclusion that the production of consistently high-grade concrete (cube strength varying between 5,500 and 7,500 lb./sq. in.) is not to be gained by slavish dependence on the weighing machine and the sieve analysis. Rather it is attained by understanding that concrete mixing is a minor art in which the engineer and the mixer foreman both play vital parts. The foreman's success depends on his mastery of the art of controlling the water/cement ratio, the greatest single factor in the production of consistent mixes ; the engineer's part is to ensure that all ingredients, especially the cement, are properly stored before mixing, to spot changes in grading of sand and aggregate supplied and adjust the mix proportions accordingly, and to see that the batching and mixing machinery remains in good order, is kept clean and checked for accuracy. Constant slump or compaction tests and regular cube tests must of course be insisted upon. No one thinks twice about insisting on a high standard of skill in a carpenter. Why should not equivalent skill be expected of the concretor ?

One has heard the opinion frequently voiced that it is beyond the capacity of field engineers to cast concrete elements to the fine tolerances which prefabrication demands. This defeatist attitude cannot be too loudly denounced. Good design will ensure that joints are simple and uncomplicated, and if this care in design is extended to the steel or light alloy moulds, and up-to-date vibrating equipment is available for consolidating the concrete, there is no reason whatever why any non-specialist R.E. unit should not be able to set up and successfully run an efficient pre-cast concrete factory. With the requisite jacks and anchorage equipment such a factory could easily be extended to produce standard prestressed elements on the " long-line " system. Under adverse weather conditions, such as persistent frost, production would, of course, be vastly more difficult. Considerable research has been conducted into this problem recently in Canada, and the solution lies in weather-proof sheds and special equipment for heating the concrete constituents and moulds.

Prestressed Concrete Bridges

One of the most striking engineering developments of recent years is the number of new prestressed concrete road and railway bridges that have been erected, especially in those areas of north-west Europe devasted during the 1939–45 war. This development is not confined to Europe, and many such structures have been built in French North Africa and elsewhere. There is little doubt that this is also the case in the Russian dominated countries of Eastern Europe, such as Czechoslovakia. Military engineering problems immediately arise in connexion with classifying and destroying such bridges, but before either of these problems can be solved, some means must be found of recognizing a prestressed concrete bridge. This may not always be easy.

Though prestressed concrete bridges may in the future conform to every possible type (including balanced cantilever, triangulated and bowstring structures), at present they fall into four main categories : simply supported slab/beam, continuous beam, two-pin arch, and fixed arch. Of these the simply supported types are by far the most numerous, having been employed exclusively for railway work and for the majority of road bridges of spans up to 200 feet. Slab bridges are not economical for spans of more than sixty feet.

The characteristic feature of a p.r.c. simply supported beam is that, unlike a r.c. beam, it usually has a bottom flange (Fig. 1). This category is therefore easily identifiable. The slab is more difficult to recognize, consisting as it does of rectangular section beams, formed into a slab by means of transverse prestress. One way of spotting this is by picking out the longitudinal lines of cleavage between the beams on the soffit of the slab. These should be visible, as the soffit of a bridge would seldom be given a finishing coat to conceal such construction joints. Another clue would be the bosses or ribs occurring at intervals on the side of the slab or edge beam (Fig. 2). These are formed to cover the transverse prestressing anchorages and are a frequent feature of all types of prestressed concrete bridge.

No great difficulty should be experienced in recognizing long span concrete bridges, as will be seen from the accompanying illustrations. Continuous beam bridges have the unusual feature of tapering to the abutments (Figs. 3 and 4), while arched bridges are of noticeably light construction at mid-span (Fig. 5). Individual arch ribs will again have the characteristic bottom flanges (Fig. 6).

Many p.r.c. bridge members are of box-section. In these the prestressing cables occasionally run, not in the concrete, but in the airspace between transverse diaphragms. The convenience of this from the point of view of demolition needs little emphasis, but care should be taken not to be misled, on finding such cables, into

Figure 3.—Bridge at Sclayn, Belgium. Typical example of continuous beam construction, with beams tapering towards the abutments.

Figure 4.—Bridge at Neufchatel-en-Bray. A continuous beam structure showing thickening construction at piers, and tapering to abutments.

Prestressed Concerete and the field Engineer 3,4

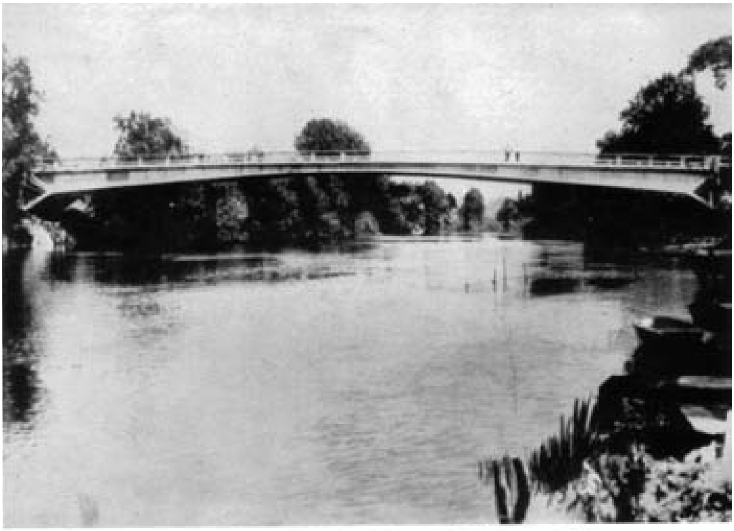

Figure 5.—A slender arched bridge over the Marne at Esbly.

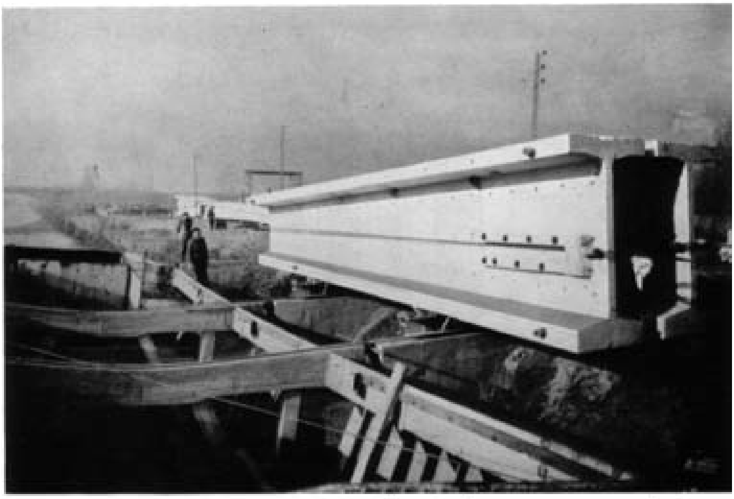

Figure 6.—Pre-cast sections of the Esbly bridge showing temporary prestressing for transportation to site.

Prestressed Concerete and the field Engineer 5 , 6

assuming that they necessarily comprise the entire reinforcement. In the Neufchatel-en-Bray bridge, for example (Fig. 4), beams are stressed as simply supported members by internal cables, and continuity over the supports is all that is achieved by the visible cables running between the beams.

Load Classification of Prestressed Concrete Bridges

Prestressed concrete bridges are all of recent construction, but in spite of this, it cannot be assumed that they will carry the heaviest military traffic loads. Bridges on main traffic routes abroad are designed on similar lines to those in the United Kingdom and cannot be guaranteed, without restriction of traffic lanes and vehicle spacing, to more than Class 60. All bridges may, therefore, have to be classified, and methods must be evolved of doing this. It is suggested that the military importance of having unrestricted movement at maximum speed on certain main routes may be so great, that classification may sometimes be required to great accuracy. In such cases, specialist troops equipped with electronic strain gauge equipment and a standard moving load should do the measurement. For 99 per cent of bridges, however, classification would, as always, be the responsibility of field engineer troops, and they will require a simple formula or histogram from which to estimate the load classification of prestressed concrete bridges.

Demolitions

Of the demolition of p.r.c. bridges little can be said here, other than that the problem is entirely dissimilar to that of reinforced concrete. The resilience of this form of construction renders concussion methods ineffective, and more fruitful results would probably be obtained by treating the main members of such bridges in a similar manner to steel girders. In some circumstances, where post-tensioned, prestressed members are used, and no grouting of cables has been carried out, prestressing cables may be vulnerable at midspan, or at abutment anchorages.

Repair and Strengthening of P.R.C. Bridges

If damaged p.r.c. spans require repair or strengthening it is more than ever necessary to understand the principles of the system and to master in detail the design of the particular bridge. If spans are to be reduced, it is best, as in r.c. bridges, to avoid reversing bending moments. If, however, it is essential to do this, it will be possible in some cases to apply the necessary prestress between anchorages bolted to the webs of individual bridge members (see Fig. 6). This method might also be extended to the strengthening of ordinary reinforced concrete bridges.

Conclusions

It is not to be assumed from this eulogy of p.r.c. that it is to be regarded as a panacea in military any more than in civil engineering. Prestressed concrete has not the wide adaptability of structural steel, nor has it the many uses of timber. It is not the invaluable aid to local improvisation that timber is. Reinforced concrete does not demand high-tensile steel wire, and fabrication is far less demanding of skill and supervision ; yet for many structural purposes it is equal to or the superior of p.r.c. Prestressed concrete, however, clearly has a valid claim to take its place among the military engineers' skills, and can provide unique opportunities to save transport and material in the field.

Such opportunities will not be realized unless, in case of war, type designs are ready, and Engineer Reserves are supplied with the necessary equipment, including efficient modern elevating, weigh batching and mixing plant. Most important of all, officers of every seniority must understand the principles of the system, junior officers must be capable of organizing the efficient production and placing of high-grade concrete ; and N.C.Os. must be trained and be given practical experience in concrete making technique and in the niceties of mix control, concrete consolidation and curing.

Acknowledgement

All the illustrations in this article are reproduced from photographs kindly loaned by the Cement and Concrete Association.

B. R. or B. M.?

Readers of the article " B.R. or B.M. ? " published in the June, 1954, issue of *R.E. Journal* will be interested to know that the author, Colonel T. I. Lloyd, D.S.O., M.C., is to read a paper entitled " Potentialities of the British Railways' System as a Reserved Roadway System" at the Institution of Civil Engineers on 26th April, 1955.

ERRATUM

A Nomogram for Friction Loss in Pipes

In the article on " A Nomogram for Friction Loss in Pipes " published in the September, 1954, *R.E. Journal*, a draughting error occurred in Plate I on the P line, lb/in.^{2} per mile. The 50 graduation should read 55 and the correct 50 inserted at 1.44 ($1\frac{7}{16}$) in. from the base.

CORRESPONDENCE

DEWATERING

(*R.E. Journal, September*, 1954)

The Editor,
The Royal Engineer' Journal.

C.E. Branch,
G.H.Q., M.E.L.F. 17.
12th October, 1954.

DEAR SIR,

There was one important point which I consider was missed in the otherwise excellent article on " Dewatering " in the September issue of the *R.E. Journal*, this was, the alternative use of the " Miller Well Point " equipment for producing a potable water supply.

At one stage during the late war, a unit in which I was serving, was faced with a problem of producing a potable water supply in a country in which this commodity was extremely scarce and for which we would have neither time nor equipment for deep boring.

Professor King, O.B.E., M.C., F.R.S., who was at that time serving as S.O.R.E. Geology with the Home Forces, was called in to give advice on the problem.

After studying the geological features of the country, the Professor said there was water in the coastal sand dunes. He further explained that in most coastal dunes a belt of fresh water could be found lying on the salt water, due to the difference between the specific gravities of the two waters, and could be extracted by the " Miller Well Point " system.

No one in our party had seen or heard of this equipment, but the Professor knew of one such installation which was producing 3,000 gallons per hour of potable water from sand dunes in South Wales.

After visiting the installation, the War Office was persuaded to purchase a complete set of " Miller Well Points," less pumps, and trials were carried out at Bogside, Ayr, etc., with great success.

The jetting was carried out by the Mono Pump of the standard water purification trailer, as was also the pumping.

I have not space in this letter to enter into the details or pitfalls of using such equipment for a potable water supply under such circumstances, but naturally the aim is not to lower the water table to any appreciable extent, but to have 12 points spaced at say 12 ft. intervals, so that the cone of depression is slight and the fresh water belt only penetrated for a few feet.

In conclusion, I would like to add, that the set can be put down and operating under normal conditions in under two hours, which makes it a valuable item of field equipment.

Yours faithfully,
T. CREECH,
Major, R.E.

BOOK REVIEWS

MENACE IN MALAYA

By HARRY MILLER

(Published by George G. Harrap & Co. Ltd. Price 15/-)

Menace in Malaya looks like becoming a best seller in Malaya and earns almost universal approval from the many classes of the community whose activities are chronicled therein. This approval is won by the fairness of the comment and the accuracy of the reporting.

The book starts with a description of how Communism first came into existence in Malaya in the 1920s. Then it was a political movement only, with all the familiar trappings of Communism.

The nature of Communism in the Far East is then described. It originally stemmed from Moscow ; and the contortions of the Chinese Communist Party in Shanghai, Hong Kong, Siam and the Netherlands East Indies, as those territories were then called, are described.

We see Communism in Malaya becoming anti-Japanese as well as anti-British. We see it hindering the Malayan (and therefore the British) war effort from 1939 till Russia entered the war on the side of Britain in 1941. We see the British High Command and the anti-Japanese Communists thrown into each other's arms when Japan attacked Malaya in December, 1941. The author traces the growth, from small beginnings, of an armed force in the jungle, partly Chinese and partly British.

As we turn the pages of this book we perceive the rift growing between the Chinese Communists and the Government. We see the Communist jungle fighters disarmed. We see them revert to violence and return to the jungle. All this is very well set forth with " chapter and verse."

Next, the author shows the Government, first haltingly and then with more determination, set out to tackle a difficult situation. We see the planters, the police and the people calling upon Sir Edward Gent, the High Commissioner, to take firm measures ; and his reluctance to do so. We see the fearful difficulties of the Government with no plan, no troops and an insufficient police force. We are made to admire the courage and determination of those on the spot fighting with inadequate weapons.

Sir Edward Gent was killed in an air crash on his way home and Sir Henry Gurney replaced him. We see in him a brave man both physically and morally. We see him grappling with the people, weaning them from Communist allegiance. Next came more troops and General Briggs as Director of Operations, to whom is attributed the Briggs Plan. This was the first effective measure to fight the bandits.

The basis of the Briggs Plan was to collect the scattered squatters into settlements behind barbed wire where they could be protected by the police from the marauding bandits. Next the efforts of the Civilian Administration, the Police, the Planters and the Army were properly co-ordinated by a succession of joint committees. We see this plan beginning to have its effect when Sir Henry Gurney was ambushed and killed on the road to Frazer's Hill ; and we feel the shock this caused to Government and people.

Morale sank to rock bottom, General Briggs went home, his contract for a year completed, and a Conservative government came into power in Britain. The Secretary of State for the Colonies, Mr. Lyttelton, visited Malaya and toured it like a whirlwind. He saw what was needed and early in 1952 General Templer arrived as High Commissioner.

The new High Commissioner arrived with a brief from Whitehall to restore law and order and then to advance the Federation towards independence. He electrified everyone by his energy, his enthusiasm and his direct approach to the problems that faced him.

A turning point in his career as High Commissioner came in March, 1952. The water pipe supplying the small town of Tanjong Malim was cut by Communists. The District Officer Mr. Codner (made famous in the book *The Wooden Horse*) and Mr. Fourniss of the P.W.D. went with a police escort to view the damage. The party was ambushed by the Communists, who had planned the whole affair, and both Europeans and seven policemen were killed while others were wounded.

The High Commissioner swept into Tanjong Malim with a squadron of armoured cars, surrounded the village, summoned the big-wigs and harangued them. They sat in hostile silence and a twenty-two hour curfew was imposed.

In Malaya opinion was mainly favourable to this drastic course. In London opinion was sharply divided ; but the Government supported its pro-consul and the High Commissioner's name was made. People in Malaya began to feel that now things were really going to happen. Communist incidents began to drop, morale soared and local politicians emerged from their lairs to shout the odds on Independence.

The author traces the ups and downs of the struggle till General Templer left in a blaze of glory in 1954 after two years at the helm.

Everyone who lived through the times will applaud the accuracy and sentiment of this book. To those who want to learn the story I commend it strongly ; but it is not light reading and the many initials make it difficult for the unitiated to follow in some places. The photographs are dull, and it is odd that of all the types of soldier portrayed the Gurkha is omitted. However, it is a good book and the only one I have seen that gives a balanced account of Communism in Malaya, and the steps taken to combat it.

M.C.A.H.

AUSTRALIA IN THE WAR OF 1939–54
GREECE, CRETE AND SYRIA

By Gavin Long

(Published by the Advertiser Printing Office, Adelaide. Price 25s.)

This is the second of the seven volumes, which are to form the Australian official history of the Australian Army in World War II. The first volume entitled *To Benghazi*, also written by Gavin Long, was reviewed in the *R.E. Journal* of December, 1953.

The story of Greece, Crete and Syria is far more beset with pitfalls for the military historian, than that of the earlier Australian triumphs against Italy in North Africa. For many years to come, argument will rage about the wisdom of sending Commonwealth troops to Greece at a time when North Africa was so nearly won. However this may turn out, Greece in 1941 will always be remembered as an example of policy pursued in time of war without the military power required to carry it out successfully. In some respects, it recalls Canning's expedition of Sir John Moore and a British force of 26,000 men to Salamanca to help the Spanish patriots against a French army 200,000 strong led by Napoleon in person. Sir John Moore had to retire fighting for 200 miles to Corunna and was killed in the battle, which was to cover the re-embarkation of his army.

The Commonwealth force sent to Greece finally numbered about 58,000 men and the Germans deployed ten divisions in Greece, of which three were armoured : the roads would not carry any more. The fighting withdrawal of the Commonwealth troops for more than 300 miles, mostly on one road, with the loss of only one combatant unit will be classed by posterity as a notable achievement.

The decision to send troops to the Balkans no doubt originated with Winston Churchill, who in those critical days towered above all around him. Yet anxious as he was to help the Greeks, the evidence in this book seems to suggest that the expedition would never have sailed if the Prime Minister himself had attended the fateful conferences held in Athens at the end of February. But in Athens the remaining impulse of his original wish to help seemingly continued to animate those, who were acting for the British Government. And so the die was cast.

The battle for Crete was such a close-run affair that the hazardous German air-borne attack might well have been utterly destroyed, if greater attention had been paid to the defences of the island during its six months occupation by British troops. Crete, at any rate, sickened the enemy of this form of warfare and may even have accounted for the almost inexplicable failure of the Germans later on to invade Malta.

Although the author suggests that the seizure of Syria could possibly have been deferred to a less inopportune moment, the immediate action taken by the British Government to anticipate Hitler seems, even in retrospect, to have been thoroughly sound. The successes in Iraq and Syria undoubtedly calmed down the Levant at a time when a sedative of one kind or another was badly needed.

The Australian and New Zealand contingents seem to have been sent to Greece after references to their commanders and to their Governments, which can hardly be considered as very satisfactory. The command structure is also a matter which in this volume begins to bedevil the higher conduct of operations in the Middle East, where Dominion troops were playing such an important part.

Mr. Long handles all these thorny problems with the same admirable impartiality, restraint and respect for the truth which were conspicuous in *To Benghazi*. This second volume is a notable contribution to the history of the war in the Mediterranean. A reference in the preface to Chester Wilmot as the writer of the next volume on Tobruk and El Alamein is a sad reminder of the untimely death of this great historian.

B.T.W.

THE MARSHALLS : INCREASING THE TEMPO

(Published by the Historical Branch—H.Q. U.S. Marine Corps)

This is the fourteenth monograph on the operations of the U.S. Marine in the Pacific and the seventh to be reviewed in the *R.E. Journal*. The story now reverts to the earlier days of " island hopping ", when the U.S. High Command was working out the complicated technique of this new form of maritime warfare. Possibly this delay in describing the capture of the Marshall Islands, is due to the task being complicated by radical changes in the original plan, which was not approved in its final form until 30th December, 1943. Nevertheless the attack went in on 31st January, 1944, which is a tribute to planners and executants alike. An important issue, which also had to be settled, was the question of the status of the Commander on land and the exact moment of his taking over charge of the operations. In the old days, the high-water mark used to be the clear cut dividing line between the admirals and the generals. This practice may clearly require modifications, when all the air action and a tremendous volume of artillery fire are under naval control. Judging from the photographs of the very determined looking men who argued the matter, the discussion was probably a lively one. The final decision was that the landing force commander was entitled to assume command on shore, when he judged that the situation permitted it.

Two specially designed Amphibious Force Flagships made their debut in the capture of the Marshalls. They housed the naval and landing force staffs and were provided with every conceivable kind of telecommunications. Airborne television equipment, able to give these flagships a view of the landings, was already a practical proposition, but the U.S. Navy did not acquire any until nearly the end of the war. The Marshalls were made good very quickly as part of the air and naval communications through the Central Pacific. The job only took a few days at a cost of under 4,000 casualties. As became customary, a number of islands full of Japanese were by-passed and left to starve. The clue to the great success of the enterprise was the bold decision to capture Kwajalein right in the heart of the Marshalls. The Japanese expected to be attacked on the fringes. The detailed maps are excellent, although it is difficult sometimes to discover where exactly some of the islands are, e.g., Roi-Namur.

B.T.W.

GREEN BERET, RED STAR

By Anthony Crockett

(Published by Messrs. Eyre & Spottiswoode. Price 18s.)

Apparently Caesar wrote *de Bello Gallico* in the third person, which is perhaps one of the reasons why schoolboys con it without much enthusiasm. Yet narrative in the first person can easily become too much of a good thing, if the writer loses control of his prose. Major Crockett does not offend like that. He writes admirably. His picture of the Malayan scene stands out clear and true. Some of the many who will eagerly read *Green Beret, Red Star*, may regret the use of native names for the commoner features of the Malayan landscape. Scores of readers, to whom *lalang* is only a tiresome word in a glossary, would be at once familiar with elephant grass. Nor does the author spare us continuous reference to the other glossary of initials, which are, in general, one of the pests of military literature. But these trifles scarcely mar a well-told story, which redounds greatly to the credit of the author and his Marines.

Communist activities in Malaya seemingly have a general trend, but are, in themselves, very local. A day's march in thick jungle is only a few miles, so that a strip only five to eight miles square, close to plantations and tin mines, may be the focus of a gang of bandits. It will continue to be so, until the forces of law and order, such as Major Crockett's "A" Troop of a Royal Marine Commando, make the area too hot for the gang, which will then move on somewhere else—" A " Troop, whose clashes with the bandits are most clearly described, seems to have played its part in the hotting-up process most efficiently in several different localities. Old hands at life in the wilds, however, will wonder whether " A " troop, when in the jungle, need have lived in the great discomfort, which is so graphically described. Even the toughest men cannot stand up long to bad housekeeping.

Green Beret, Red Star is a grand book and will be widely read, because many distinguished regiments of the Army are engaged in precisely the kind of police operations which it describes so well. For the same reason, has not the time come for the Commando organization to disappear? Surely the famous name, "Royal Marines," does not require any additional label or appendage? And it would be one complication less.

B.T.W.

THE BRITISH SOLDIER

By Colonel H. de Watteville, C.B.E., M.A.

(Published by J. M. Dent & Sons. Price 18s.)

At the beginning of this century the British Army, socially speaking, rather resembled a large association of exclusive clubs, whose activities were little known to the general public and which were for that reason rather suspect. Outside the barrack gate, the officers were at pains never to be seen in uniform if they could possibly help it, whereas for their walks abroad, other ranks had to don their full-dress tunics and pipe-clayed belts. In spite of this inequality of treatment of the soldier in every-day life, the exclusiveness of Corps and Regiment was by no means confined to the officers. Successive generations of burly sappers, large gunners, diminutive riflemen and dashing hussars followed each other into their particular regiments and maintained the old traditions. Without such assistance the already flagging voluntary system of enlistment would scarcely have filled the ranks.

The terrible slaughter of young officers and men, which marked the Kaiser's war and the social upheaval which followed, played havoc with the old Regular Army. Between the wars the voluntary system all but broke down. Hitler's war brought about a complete transformation of the structure which had been rickety for so long. National Service now makes the Army part of the life of the people of Great Britain. The general public now knows much about the Army and has at the same time developed a taste for history.

Colonel de Watteville has therefore done well to produce so opportunely, such a well written and diverting book as *The British Soldier*. For it, he has delved with scholarly selectiveness into many famous military histories which we all know but never find time to read. So busy and idle men, alike, will be delighted with the book. Its well chosen illustrations include a photograph of the Royal Artillery Memorial of 1914–18 and 1939–45 which must be one of the noblest monuments to the British soldier ever devised.

B.T.W.

STRATEGY: THE INDIRECT APPROACH

By B. H. Liddell-Hart

(Published by Faber and Faber. Price 25s.)

This is a revised and enlarged edition of the author's previous omnibus work *The Way to Win Wars*, which had an earlier title *The Strategy of Indirect Approach*. Student officers should know that Captain Liddell-Hart is a writer of international repute, and this book is virtually a standard textbook on strategy.

It is interesting, in the new preface, which disposes of nuclear warfare in less than three pages, to observe Captain Liddell-Hart departing from his own guiding principle, and carrying out a direct assault upon his reader's intelligence and susceptibilities, thereby provoking, in one reader at least, that "stubborn resistance" he himself foretells. People have their loyalties. To open with an unsubstantiated condemnation of Churchill and Roosevelt, for the victorious events of August, 1945, is no way to win over the average English-speaking reader to any prompt acceptance of the H-bomb as " retribution " upon us for Hiroshima, or of the pursuit of triumph in World War II having been futile, or of victory being " nonsense," " absurd." These things may be so, but we'll take some persuading. Meanwhile we can safely agree with the author that, with nuclear weapons in the background (and staying there), the study of strategy is fully as important as ever. T.I.Ll.

PRESTRESSED CONCRETE

By PROFESSOR GUSTAV MAGNEL

(Published by Concrete Publication Ltd., London.)

This is the third edition of this well-known book on prestressed concrete and includes the more recent knowledge of this subject with a greater variety of examples of this form of construction from all over the world. The Professor does not confine his remarks to his own system of applying prestress, but naturally he is somewhat biased in favour of his own methods. With all Professor Magnel's books, one is always impressed with the detailed calculation and experiment which he has brought about to justify his wider assumptions. In fact, this is a book for the *savant* rather than for the practical design. If you have any doubts as to the truth of any feature of prestressed concrete this is where you will find them proved or dispelled. If you want to know how prestressed concrete stands up to fatigue, fire or shock inquire within and the results of actual tests will be found to set your mind at rest.

The new edition includes a table of beams and their dimensions for various spans and loads together with the cables required, and this should greatly simplify the initial steps in design. The writer illustrates his steps in design by numerous examples which is a system of teaching which most people find more easy to follow than the straightforward discourse and use of symbols and various alphabets.

A shortcoming of this books seems to be the complete devotion paid to the span to the exclusion of the supports. One cannot help feeling that the bearings of a bridge are as important as the road bearers. It is true that the bearings are not usually in prestressed concrete, but at least some illustration of the methods used would be very much to the point.

In the criticism of his last edition we said that we looked forward to the results of his further work and there can be no doubt that engineers will not be disappointed. H.J.C.

SIGNIFICANCE OF PROPERTIES OF PETROLEUM PRODUCTS

This book contains thirteen articles which were published in 1949–50 in the *I.P. Review*. Each article deals with a property, or group of properties, of petroleum. The articles are divided into a description of the property, the reason why it should be investigated, and a short description of some of the tests employed.

The book will be of interest to the engineer engaged on work involving petroleum products, but will be of far greater use to the chemist. M.B.G.

BOOKS ALSO RECEIVED

The Steel Skeleton, Volume I, Elastic Behaviour and Design, by J. F. Baker. Published by Cambridge University Press. Price 42s.

Strength of Materials, by Arthur Morley, eleventh edition. Published by Longmans Green & Co., Price 21s.

TECHNICAL NOTES

THE MILITARY ENGINEER

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

JULY–AUGUST, 1954

"Defence against Radiological Attack," Major Dimitri A. Kellogg, Corps of Engineers.

The author, born in China of Russian parents, graduated from the United States Military Academy in 1943, spent three years with the Armed Forces Special Weapons Project at Los Almos, graduated Ph.D. in Nuclear Physics in 1952, and is now serving at the Naval Radiological Defence Laboratory.

The very limited use made of surface and sub-surface bursts in more than eighty atomic detonations already set off by the United States has been quite inadequate for the effective test of the contamination possibilities of such low-level attacks. In his opinion these early trials of atomic weapons have over-emphasized the effects of blast at the expense of radioactive contamination, the effects of which have so far tended to be minimized. A revival of interest in radioactive contamination as a prime military effect of atomic weapons, has followed the closer investigation of atomic attacks on hard targets such as ports, shipyards, and arsenals, where high peak overpressures are required for effective damage to vital points. Proximity bursts of this nature produce heavy contamination over an area larger than the area of destruction, and most published documents on atomic defence to date have under-estimated the need for adequate measures to be taken against such contamination. A joint Naval and Army Corps of Engineers project team, of which the author is a member, has studied the problem in detail over the last three years and one result has been the production of a manual for the instruction of Engineer officers in radiological defence, "radiological recovery of fixed military installations."

The manual approaches the problem under the three main heads : intensity of radioactivity to be expected ; effect of radiation dosage on personnel ; degree to which counter measures can reduce the dose to personnel. Simple tables show the price that must be paid in terms of equipment, manpower, and radiation dosage to recover the use of an installation at any given time after radioactive contamination.

As there has been no opportunity to experiment with large-scale reclamation after a contaminating attack, the manual is necessarily imperfect, but in spite of this it is being issued to the user, both for use in case of emergency and to obtain constructive criticism with a view to improvement in present techniques.

"The Dual Rôle of the Army Engineer," Major-General Samuel D. Sturgis, jun., Chief of Engineers, United States Army.

In a refreshingly written article the author emphasizes the dual liability to the engineer officer to combine all the qualities of military leadership with the highest degree of technical skill. A good officer who has not learned the basic principles of engineering is no more an engineer officer than an honours graduate of engineering who lacks the soldierly qualifications of military leadership. Among other essential military standards defined, acceptance of a commission entails obligations beyond those of other citizens ; including conduct in public and personal affairs measured by standards far more exacting than those normally met with in civil life.

The first attribute of character is held to be truth and the General condemns a growing tendency in the United States towards subterfuge, or as it is more commonly called to-day, expediency; cleverness is no substitute for integrity. The temptations that exist in the incidental gifts offered by contractors and in the personal use of Government facilities and property are dealt with. The reputations of the Corps of Engineers is directly dependent on the integrity of its officers. In conduct and appearance men reflect their leader's character as truly as a mirror reflects an image. The principal reason for the failure of many officers to reach high rank is not so much their lack of skill or knowledge as it is lack of physical stamina and fitness.

Dealing with engineering standards required to obtain the essential proficiency in the science of military engineering, the author holds that no engineer officer, who wishes to reach high command, should permit himself to become a specialist early in his career. Most large operations are diversified in nature and, consequently, are seldom commanded by specialists.

The author emphasizes the value of retaining the Civil Works Division and Districts within the Corps of Engineers both as a technical training ground and as an effective contribution to national defence. The first and greatest bottleneck in mobilization is construction. Until the necessary plants and installations are built, the future of the nation will rest in the hands of constructors. The ideal solution lies in the continual readiness of the large, flexible construction force in the Civil Works organization of the Corps, which in time of emergency can be quickly diverted to military construction. If the construction activities of the Corps are limited in peace to the almost insignificant military programme the Corps will not be in a position to expand as it did in 1940 to take on a construction mission of 4 billion dollars a year.

The necessity for economy in both military and civil construction is stressed. The good engineer officer will safeguard Government funds with as much care as he would his own capital. To neglect an opportunity to save funds by efficient administration and cost controls, by reasonable design specifications, by sound advance planning, and by proper maintenance, is to neglect his managerial duty.

ENGINEERING JOURNAL OF CANADA

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

The North-west Highway System

The North-west Highway is the Canadian portion, 1,221 miles long, of the Alaska Highway, which was of such vital importance when the Japanese threatened Alaska during the 1939–45 War.

This paper describes succinctly the geography and topography of the region traversed, and sets out very clearly the problems to be faced by road and bridge engineers as a result of varying soil conditions, both in " temperate " climates and where permafrost is encountered. The author's account creates a very live picture of natural conditions, of the mistakes made during the original hasty location and construction of the route, and of the task of maintenance and long-term improvement. The description of the organization adopted for maintenance work is of particular interest.

The examples given of Nature's reply to unsound planning, and of the practical factors involved in construction in cold climates, cannot fail to give the reader a better understanding of the art of road building.

Transistors and the Electrical Industry

The invention of the transistor, first made public in 1948, was hailed as the greatest step forward since the vacuum tube and, by 1952, it was predicted that it would shortly revolutionize electronic design (see Technical Notes, *R.E. Journal*, December, 1952). Transistors are not yet, however, widely used commercially, except in some telephone equipment and by some hearing-aid manufacturers.

After a very clear and thorough description of transistor-action and design, this paper discusses methods of manufacture and explains the apparent delay in development.

Manufacture entails the manipulation of components under a microscope and new techniques are called for by the rigorous cleanliness and critical dimensions involved. Machinery for large-scale precision production is still under development. Since the characteristics of transistors are radically different from those of vacuum tubes, new ranges of associated components have had to be devised, and circuit designers re-educated.

Transistors are now becoming available in reasonable quantity, and being developed in forms capable of controlling relatively large power inputs. It seems clear that they will shortly be used in power control circuits and industrial electronic equipment, even if, for the time being, mainly in hybrid tube-transistor assemblies. Meanwhile, their potential value for computors, predictors, radar, guided missiles and similar military purposes is manifest.

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

Location and Construction of the Quebec Northshore and Labrador Railway

The original reconnaissance of the Labrador Railway in 1945 was described in the April, 1954, issue of *The Engineering Journal of Canada* (see *R.E. Journal*, September, 1954). This account of the subsequent location and construction of the railway is of particular interest in that it describes briefly but graphically the whole process of preliminary survey, final location and construction in difficult country with widely divergent soil characteristics, in a climate with a temperature range from about − 55°F. to 100°F., frequent though not excessive rainfall in summer and snow cover up to four feet in winter.

One of the main lessons to be learned is the value of aerial survey in driving a route some 360 miles into an unknown country. In this project, although two attempts were made to use air photographs for location survey, both failed owing to inadequate ground control.

The organization for field survey is very interesting, especially in regard to the complementary methods used in summer and winter respectively, and the description of construction procedure contains valuable practical information about the use and maintenance of plant, the use of explosives, problems of soil treatment and drainage, and the organization of communications, supply and construction teams.

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

Canadian Niagara Developments

For over sixty years the waters of Niagara have been used for generating electricity, and the visit of the Duchess of Kent during this summer marked another stage in Canadian power development.

The Engineering Journal of Canada for November, 1952, described the planning and organization of a project to produce some 1¼ million additional horsepower (see *R.E. Journal*, March, 1953). The August, 1954, issue contains two papers which give much interesting information as to development and design. The first tells the general story of hydro-electric development at Niagara and describes and compares the main features and construction of the two most recent projects. The second discusses transmission lines.

Of particular interest is a table comparing various features of the No. 1 Plant, built between 1917 and 1930, and the No. 2 Plant, scheduled for completion in January 1956; and the advance in the design of transmission lines, achieving a tenfold increase in design-load between 1910 and 1953.

Underwater TV and its Application

The value of the underwater television camera has been strikingly proved by the identification of H.M. Submarine *Affray*, lost at sea, and the more recent location of a foundered aircraft.

This account of the development and trials of equipment makes interesting reading. Those previously unacquainted with the operating principles of TV, but not unduly nervous of electrons, synchronizing pulses and dynodes, will gain some understanding of "how it works," but this is not essential for appreciation of the practical trials carried out, nor of the wide field of potential application suggested.

The particular value of this system of wired television is, of course, that the view in front of the camera below water is immediately available on the viewing screen on a surface craft, and that the device is free from human limitations as it can be moved and turned or tilted by remote control. Photographic records can also be made.

Apart from scientific applications, in aquatic biology and fishery research for example, and the scanning of underwater structures, demonstrations and training films of underwater activities should be much simpler to produce. The equipment also has a laboratory value for the remote viewing of dangerous areas, and it has already been used in the study of de-icing problems on the intake of a jet engine.

CIVIL ENGINEERING

Notes from *Civil Engineering*, June, 1954

Unit Bridge Construction

Starting in this month's edition is a series of articles on unit-construction bridge systems. It starts with a description of the Callender-Hamilton bridge which has been redesigned, although it still retains the familiar Warren type truss in its construction. The bridges cover a range of spans from 40 to 200 ft. As a military bridge the Callender-Hamilton merits consideration for use in the Communications Zone. It has one big disadvantage for that purpose in that it uses steel which will undoubtedly be in short supply in time of war. The manufacture of replacement bridging in steel as a theatre project was done in Italy during the last war and it is comforting to know that designs such as these already exist which can be quickly put into use.

Also described in the article is the increasing popularity of the high tensile steel bolt for bridge construction in America. The bolts are stressed up by tightening the nut on to its screw by compressed air wrenches. This system of bolting will probably be used on future military railway bridges.

The next articles in this series will be of great interest to every sapper.

Harbour Structures

The International Navigation Congress held last year in Rome produced a number of interesting points in the construction of harbours and the training of rivers. An article in this month's review covers the field of discussion of the conference. One of the most interesting parts of the article is the means available to prevent corrosion to harbour structures and the means of combating the toredo beetle. It is apparently possible to kill the beetle by periodically firing small explosive charges in the water close to the piles of a wharf.

Reinforced Concrete

The student of concrete design will find new thought in the summaries of papers produced as an article. It represents papers given at a symposium recently organized by the Cement and Concrete Association, and covers a wide field including the effect of steam curing on mix design, the variation of concrete strength with different degrees of site control and the difficulties encountered in trying to produce high strength concrete.

New Plant

Contractors' Plant reviewed here is most interesting this month. The large mobile Coles crane is described. This crane has a lift of 41 tons and is lorry mounted with twelve forward and three reverse speeds. The makers of the Matbro humper have now produced a front loading bucket on the same chassis. The bucket has a capacity of 1 cu. yd. which can be replaced by forks, crane or dozer blade to provide a most versatile machine. The large wheels at the front are the driving wheels and give it good cross-country performance.

Notes from *Civil Engineering*, August, 1954

Texas Expressways

An interesting article appears on American highways and is based on a paper presented before the Institution of Highway Engineers. During the post-war years most of the individual American States have found it necessary to develop a so-called " super highway " to accommodate increasing motor vehicle traffic. A family of names has been created to designate this high type highway and to differentiate it from the ordinary highway or road. The A.A.S.H.O. has formulated official definitions for the " super highway " and has limited the terms to Expressway, Freeway and Parkway :—

Expressway — A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at intersections.

Freeway — An Expressway with full control of access.

Parkway — An arterial highway for non-commercial traffic with full or partial control of access and usually located within a park or a ribbon of park-like development.

The Controlled Access Expressway is a simple device for removing all possible traffic conflicts. In its ultimate and complete form it provides for the separation of all crossing traffic ; turning traffic in the through lanes is prohibited and direct access to and from adjacent lands is impossible. Generally, predicted traffic volumes of 20,000 vehicles per day within twenty years will justify the development of an Expressway, which is estimated to cost from five to ten times as much as an ordinary highway.

From the pavement design point of view, actual wheel loads in Texas have been assessed at a general maximum of 13,000 lb. but in the design of Expressways, an increase of 50 per cent over the useful life has been assumed and the design caters for a 20,000 lb. wheel load.

Expressways pavement design is usually of flexible type consisting of between 12 in. and 18 in. depth of granular base material, depending on the subgrade, and a " black top " three to four inches thick. On the urban Expressways however, the predominant pavement material is concrete of about ten inches thickness laid on a 6 in. flexible base.

The usual cross section consists of two 36 ft. wide carriageways separated by a 4 ft. wide median 6 in. high. The carriageways are flanked by 10 ft. wide refuge shoulders and an underground storm drainage system is provided.

Industrial Uses of Gamma Radiography

Many readers will be aware of the wide uses of X-ray radiography for inspecting castings, welds, forgings and similar large metallic parts for flaws such as cracks, inclusions, porosity, etc. A similar technique, namely gamma radiography, is becoming increasingly popular in the engineering industry because it is cheaper and easier to use, and requires less skilled personnel. Gamma radiography of course is not a new science and has been known since the end of the last century, when Roentgen and Becqueral discovered radioactivity and the related phenomena. Great Britain, however, has led the world in the application of useful isotopes in general, cobalt and caesium, which are both derived from the atomic pile, being used for gamma radiography. Caesium in particular is an interesting source, as it is in fact extracted from the waste elements and is a pile by-product.

Gamma radiography is used in two main fields at the moment ; in the foundry for testing castings, forgings and large welded equipment, and in the field for testing ship's bottoms, propeller shafts, major components in mine shaft gear, bridges, heavy girders, and chemical equipment such as catalytic cracking units, oil pipe-lines and steam lines in power stations.

A particular advantage for this site work is the ease with which the gamma source can be inserted into confined spaces, e.g. narrow, welded pipe. This would not be possible with the normal X-ray set, owing to its greater bulk.

Effects of Vibrations on Soils

This is a most useful article, especially to the mechanical or civil engineer who may be concerned with the design of foundations for very heavy machinery.

The resistance of soils to static loading has been extensively studied during recent years, and it may be said that the problems involved are fairly well understood. There remains another factor which requires a more complete investigation, and this is the resistance of soils to vibrationary or slow repetitional loading. The article includes a table showing the natural frequency of numerous soils, and a detailed description with a drawing of the massive foundation provided for the 500 ton power hammer installed at Distington in Cumberland. The tup weighs 25 tons and drops through 6 ft., the anvil weighs 380 tons, and the reinforced concrete foundation together with steel beam grillage weighs 3,000 tons.

Reinforced Concrete Cylindrical Shell Roof

When a large span roof giving maximum working space is required the concrete cylindrical shell is an efficient and economical answer, as well as having clean and pleasing lines.

There are two approximate methods in use at present for the design of shells; they are based on the "Beam Theory" and the "Membrane Theory". The former is applicable when the length of the shell is at least $1\frac{1}{2}$ times the width, and the larger this proportion the more accurate the application. The article considers design by the "Beam Method" and gives a very clear analysis of the stresses involved, including a worked example for a shell roof 100 ft. long and 42.5 ft. wide. The super load is 20 lb./ft.^{2}, and permissible design stresses for concrete and steel are 1,000 lb./in.^{2} and 18,000 lb./in.^{2} respectively.

The modular ratio, m, is taken as 13, and the section is required to resist a maximum bending moment of 4.1 million lb. ft. The shell as designed is only 3 in. thick.

Review of Contractors Plant

It is becoming increasingly popular to fit hydraulically operated excavating equipment and hoisting equipment to standard crawler tractors. Two new attachments are described in this edition, firstly the new Marshall side boom Tractor Crane and secondly the Allis-Chalmers H.D. 5G Tracto-Shovel fitted with a trench hoe equipment.

The side boom tractor crane is particularly suitable for handling large pipes on a difficult site for a pipe-laying project. The equipment is easily fitted to either a Fowler Challenger 3 or 4 tractor without any major modification being necessary. At an overhang of 4 ft. the crane can lift up to 18 tons when fitted to a Challenger 4 or up to 12 tons on a Challenger 3.

The Allis-Chalmers H.D. 5G Tractor-Shovel fitted with the trench hoe attachment can be used for excavating pipe trenches, drainage ditches and general work for foundations etc. The trench hoe bucket has a capacity of only $\frac{1}{2}$ cu. yd., but the makers claim that the attachment can excavate a trench 8 ft. deep by 27 in. wide. No doubt, this machine has a certain advantage over the normal excavator with back-actor equipment for trenching work, owing to its superior mobility, but it should be remembered that the dumping action of this equipment is achieved by slewing the tractor, and it is suggested that on certain types of ground, this may not be very satisfactory.

AMERICAN STANDARD BUILDING CODE REQUIREMENTS FOR MASONRY

(Published by the U.S. Department of Commerce, National Bureau of Standards.)

This is a complete code of minimum requirements recommended for masonry construction, including definitions and requirements for all types of masonry in the United States. It is similar to our own British Standard Codes of Practice for Building Construction and Engineering Services.

It is interesting to note that the term masonry as used in the United States is defined as a built-up construction or combination of building units of such materials as clay, shale, concrete, glass, gypsum, or stone, set in mortar; or plain concrete.

In this country masonry refers only to work in stone, the bricklayer dealing with clay products, while facing walls with glass units is the work of the specialist.

Can it be that in building there is more specialization in this country than in the U.S.?

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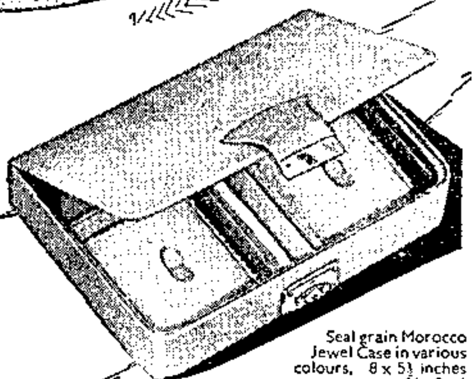

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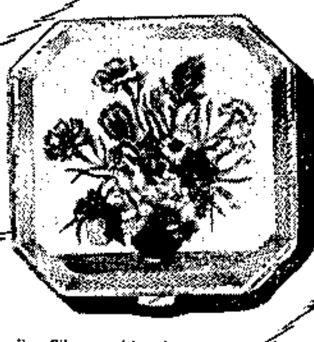

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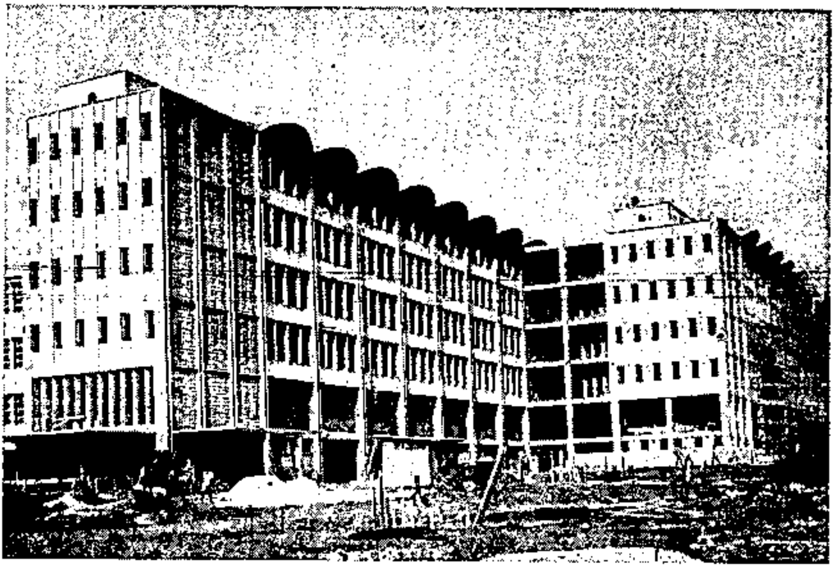

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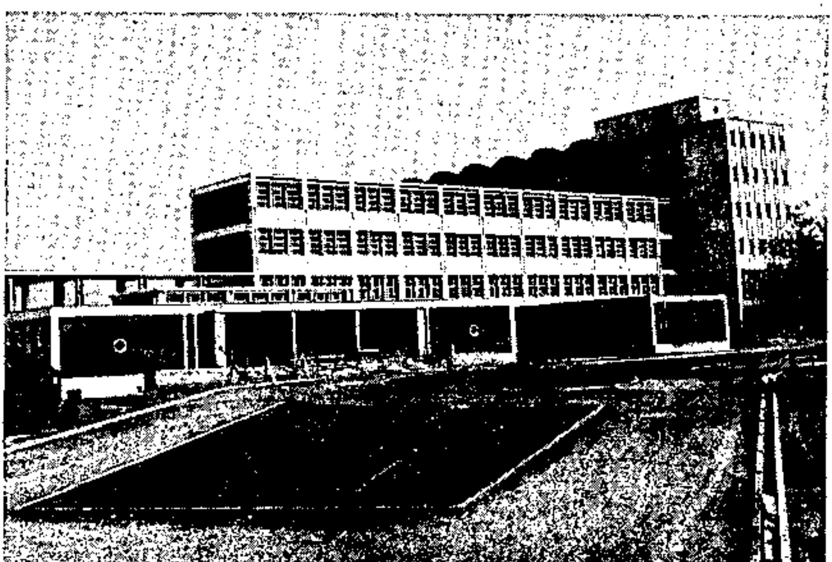

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