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Photo 10.—The Club bar.

Photo 11.—The Model Room/Theatre.

New Headquarters In Germany 10,11

NEW HEADQUARTERS IN GERMANY

(Part II)

By Colonel H. Grattan, C.B.E.

(Part I gave the history leading to the sanction to go ahead with the project, and described its planning and early progress.)

Financial Control

The preliminary rough estimate for the new headquarters project submitted to the War Office in July, 1952, for the work as it was then foreseen amounted to DM.130 million (£11 million). This was a broad estimate based chiefly on experience in the "Op. Humane" project, totalling DM.90 million, which was then coming to a close. The original estimate included percentages for contingencies both "Q" and "E" and for variations of price.

It was tempting for the staff, and indeed for us, to regard a total sum based on estimates so hastily produced, as containing a good deal of fat which could be drawn upon for *ad hoc* alterations to the scope of the project as the work proceeded. The "Q" Staff readily availed themselves of this, and we were not backward in satisfying their further demands as they arose. It would take too long in this account to show in detail how the scope of the project was increased from time to time throughout the construction.

This would not have been possible in a project conducted on Vote 8A procedure, but in Germany since the war R.E. services had been using deutschmarks from the occupational costs budget, and although money was not wasted in the spending of it, it had become a habit to change the scope of works locally, without reference to the authority who had approved the project in principle. This is a bad habit, but for a project planned as hastily as this, the practice served well to fill in minor detail.

Early in 1953, it was already apparent that extra accommodation and services would be required for new demands. For instance the establishment for Signals was raised to a L. of C. Signals Regiment for the headquarters, in place of a detachment, which in the original planning amounted to little more than a squadron. This and many more additions of the same nature were made during the course of the project, and put to contract as soon as they were authorized. Consequently the framing of revised estimates (AF.M1428) often lagged behind the execution of new work.

In June, 1953, much larger additions were made which fell within our responsibility. These were partly changes in scope which were properly chargeable to the main project, and partly additions which, though not part of the main project, were added to our load of work. Examples of such items were:—

(*a*) The building of a new office block with messes and houses and a children's primary school, and married quarters for the establishment, then known as British Intelligence Organization (Germany), which it was decided would be moved from Wahnerheide to the new headquarters site.

(*b*) The addition of 244 Officers and O.Rs. houses partly to satisfy (*a*) above and partly to augment Army and R.A.F. scales to bring them in line with the number of houses which had been occupied at Bad Oeynhausen and Bad Eilsen.

(*c*) A secondary day school for 400 which was required West of the Rhine, and might have been placed anywhere, but was at that stage reasonably sited on the main headquarters estate.

(*d*) An office block for N.A.A.F.I. headquarters moving from Bad Salzuflen.

The cost of these major additions was estimated with their services at DM.24 million. With reasonable prescience the original planning of the site and its services had left scope for these expansions.

As agency fees for a project of this size, the Germans required 3½ per cent of the cost. This had been normal practice. For this they undertook to set up the special works organization (the F.S.B.A.), accommodate and equip it, employ architects and consultants, and do all the drawings, bills of quantities, tendering and billing. By the beginning of 1954, it was becoming evident that the 3½ per cent allowed as agency fees was proving insufficient to cover their costs. In the end after much negotiation, it was decided that German authorities would be paid their *actual* costs for this project, which it would not be difficult to assess. The total sum has proved to be about 7 million Deutschmarks on this account, or about 4 per cent. (It is interesting at this juncture to note that the Ministry of Works undertakes the same duty on behalf of the War Office at home for 14 per cent.)

The factors described have brought the total estimated figure for the whole project to about 173 million Deutschmarks (£14.7 million).

Revised 1428s were from time to time submitted to the War Office to cover the increases described above. The method of conducting such a project whereby much definition of detail is left to the German authorities (and in fact by them to the contractors themselves, whose conception of a lump sum contract is not the same as that which is understood in England) gives room for much work of a higher specification than is demanded to creep into contracts. It was not always possible to stop this happening, nor to dispute the claims of contractors who might have done more work than had been strictly specified in the tenders. Further, delays and bankruptcies gave grounds for unforeseen extra-contractual claims, many of which are not yet resolved. My ground staff was inundated with deviation orders, which in theory should have been priced before work was allowed to start, but which in fact often represented the measured results of urgent work which had already been taken in hand or completed. This was, therefore, not an easy project upon which to exercise successfully a meticulous financial control.

Progress reports were submitted monthly by my office, to the Chief Engineer, based on an easily workable system whereby every Garrison Engineer was required to record on a chart the percentage completion of every building operation within his charge. A monthly compilation from the charts by my office did not present anything more than a heavy mechanical process. These monthly progress reports were the basis for the payment to contractors—through the F.S.B.A.—of running payments on account, and for the transmission of information to H.Q. Northern Army Group and the War Office.

There were some 1,500 main contractors employed and countless sub-contractors. In Germany, there are no vast building concerns such as there are in England who could have conducted the major part of the project or the whole of it. The *biggest* single contractor carried only DM.4 million of work in the carcass and roof of the main headquarters block. The housing estate was divided into many small contracts of DM.1½ million each. A number of contractors went bankrupt, eight in the married quarters alone. These and a thousand other factors complicated the task of my S.Q.S. Lieut.-Colonel Biggs (and of his counterparts in the F.S.B.A.) in keeping abreast of exact financial progress. It may justifiably be said that at no moment could we give accurate financial detail for the probable cost of every item in the project. We therefore presented a difficult problem to Engineer Branch and the D.Q.M.G.; but although the billing has not yet been completed and is not likely to be for some time, it can be said that our estimates have not been grossly exceeded in the main, and that if some details of the work cost more than we expected we managed to foresee the possibility in time for financial provision to be made.

Organizing the Move

This was not a works matter. It was, however, so complicated an operation, and one which had so much bearing on our organization, that it must find a place in this account.

On 23rd September, 1953, a conference was held in Bad Oeynhausen under the Chairmanship of the M.G.A. to rough out the principles upon which the move to the new headquarters would be planned. (It was then anticipated that the move would take place in July, 1954, though the reader may remember that works planning had only started in August, 1952.) The head of every branch at Headquarters, B.A.O.R., was represented, and the Royal Air Force sent representatives whose duty it was to observe the plan and presumably to base the R.A.F. move upon it. I was not concerned with the complicated problems of vacating and de-requisitioning accommodation in Bad Oeynhausen, which took up a large part of the time of the meeting; the existing Camp Commandant in Bad Oeynhausen, who was to remain there over the move and afterwards with rear parties and administration details, would deal with that aspect. I was, however, vitally interested in what followed, which was the plan for the receiving end.

In the new headquarters a camp commandant was to be appointed as soon as possible, whose responsibility would be to take charge of buildings as they were completed. At a later stage he would furnish the accommodation and phase in the troops and families who would arrive over a period of some months in 1954. I did not covet his job. It would be a welcome appointment, for it was vital to us to have on the site an authority to take over the finished buildings and who would be competent to guard them as they were handed over, so that neither the contractors nor my staff would incur the liability of looking after them. Most of the standard barrack buildings had started in February and March, 1953, and would be ready for handing over in the winter. Contracts with German building firms demanded that completed buildings should be taken off their hands within fourteen days of certified completion; therefore to have kept the completed buildings on contractors' hands would have been to incur a heavy extra-contractual obligation, for which no rates had been fixed. As far as I was concerned, the three most important agreements reached at the conference on 23rd September were, firstly, that a camp commandant's staff would be located on the site, secondly that a guard company of the Mixed Services Organization (a quasi-military unit consisting of Polish and Yugoslavian D.Ps.) would be posted to the site as soon as barracks with stove heating and field cookhouses could be furnished for them, and thirdly that early in 1954 a British regiment would be taken off all training duties and would be established on the site, either in tents or in completed buildings. Their task would be to take over and guard completed barracks and installations, and to see that large scale theft and petty pilfering, which were already rife, should be reduced to a minimum. This obviously would not be a welcome duty for the regiment appointed.

The M.S.O. unit, of depleted strength, duly arrived a month later, and proved most useful within their capacity. In November an interim camp commandant's staff was set up. In the following spring a light A.A. regiment was posted. They did an unpleasant and thankless task with great thoroughness and understanding. They were relieved by another R.A. regiment in the summer, which carried out the same functions until the move took place in October, 1954.

We had all feared that once great areas of building were taken out of contractors' responsibility, the incidence of theft would exceed all bounds. We saw no method whereby replacements for such thefts could be authorized without frequent and ponderous courts of inquiry, which we would not have welcomed. In the event, the greatest single theft that ever took place was the dismantling of thirteen basins from a barrack one night. Apart from this there were only a few hundred minor pilferings. Most of them were within the powers of write-off of the Camp Commandant, Colonel A. E. Wilkinson, O.B.E., M.C., of the Gloucestershire Regiment, who had been posted to the site in May, 1954, or of Wing Commander R. A. Milward, D.F.C., A.F.C., who performed the same duty in the R.A.F. Camp.

In June, 1954, the Barrack Department collected the accommodation stores in the transport garages (which by then were virtually completed) for the main headquarters offices and barracks, and married quarters. As far as was foreseeable in the fog of the contracting world, priorities for completion had been agreed mutually between us and the Germans and we engineered the handover of buildings in accordance with these priorities. By far the greatest complications arose in the main headquarters block (the functions of which were subject to changes, even at that stage), and in the married quarters estate. For the latter, by setting up a special organization for the purpose, the R.A.S.C. reckoned that they could take over and furnish fifteen houses per working day. We on our part had to try to satisfy that rate of completion. This would spread the taking-over of houses and handing of them to the Camp Commandant over a period of three months from 1st September.

The C.-in-C. had promised all families that they would be settled in before Christmas. In another paragraph I will describe the troubles which beset the process of completing married quarters, or even of foreseeing which would be first completed in their proper order of priority. The move had necessarily been organized by Headquarters Northern Army Group on a programme of planned completion dates produced by us on the data available many months earlier. It inevitably occurred that for one reason or another the construction of houses which were scheduled to be early in the handover programme had to be deferred to a later stage. Potential occupants in the H.Q. had, however, been allotted definite addresses based on the original planned order of completion in relation to their "points" entitlement to priority of moving. They heard of the various snags which deferred the handover of their particular house with telegraphic rapidity, and in consequence we were unmercifully prodded during the whole of the handover period. In the end I believe no single family was moved later than the end of the date bracket which had been allocated to them and many were surprised to be able to move earlier.

Maintenance of Completed Work

Early in 1954 a D.C.R.E. was appointed to the site, responsible to the permanent works organization of Rhine District for maintenance of completed work from Part III funds. He was Major K. H. Stevens, M.B.E., R.E. He carried the responsibility not only for maintenance but for such new works within the site which were demanded after that stage in the main project when additions to its scope could no longer be approved as a charge against it. He built up his staff largely from experienced members of mine. The passing of the baby to him proceeded with great smoothness from our point of view. We hope he thought so too.

Snags, Mistakes, Troubles and Lessons

The discerning reader, that is to say anybody who has been in charge of a project, will by this time be sceptical of the apparent smoothness which is shown in my account. Let it not be thought that there were no difficulties. I have kept a whole chapter for them because their unexpectedness and the overcoming of them is the main spice of any project, and from them lessons for the future can be learnt.

(*a*) *The Weather*

Records in November, 1952, when the roads and water mains had started, and the foundations for the first twenty-four houses had been laid, showed a rainfall 207 per cent of normal. The site which we had regarded as good draining land, was churned up into a fair imitation of the Russian Front. Heavy transport bringing in material, not to speak of the tipper wagons carrying concrete from batching plant to road head, ground their axles deep into the forest tracks. Roads of sand and gravel in the surrounding country became impossible and vehicles cut wide swathes of morass through agricultural land. The natural falls of drainage were interrupted, and the puddling of the silt surfaces seemed to make an impermiable slough against the absorption of rain. Therefore the twenty kilometres of road which had been planned to be completed by the first week in February was not finished until the end of March. The summer of 1953 showed little improvement on the winter. It was favourable only for the growth of grass.

The winter of 1953/54 was said to be the most severe for thirty-nine years. There had been normal rain up to the middle of January, but on the 23rd January a frost which held for six weeks steadily gripped the site. Most of the rivers in Germany were frozen solid, and the Rhine was a mass of pack ice from bank to bank for several weeks. From 23rd January until the end of March, underground work on the site was at a standstill.

In a normal project planned over the years and undertaken with engineering expediency, the underground services would first have been laid. Admittedly we did get the roads and water mains in during the first winter, but for the other services, drainage, heating, electricity and gas, the mere process of designing them in detail took many months. By that time, owing to the condition under which the project had been allowed to start (namely the spending of vast sums of money by impossible dates), all the building work was forced well ahead during the summer of 1953. Barracks, canteens, clubs, messes, etc., had their roofs on by the end of 1953, and the 880 dwelling houses which had started in May and June were well up, with roofs going on as the winter set in. *But very little had been done for the underground services.* It would take too long to describe the confusion and difficulties of co-ordination between the various contractors. Those responsible for underground services were all at once let loose to contend for subterranean space among the activities of building contractors bringing in materials for surface work. Impedence was terrific and tempers ran warm with friction.

It had been planned that by mid December, 1953, the heating ducts would be largely completed, and the boiler houses functioning to supply heat. This was important, because if there had been heat within the buildings, internal plastering and decoration could have proceeded during the winter. As it was, the first heat provided was from the east boiler house on the 19th January, 1954, to the main headquarters block. This building was admirably suited for the dissipation of unwanted heat during the boiler testing time. During the big freeze which followed a few days later, work was able to go on within that building by virtue of its being heated. This happy condition was not fulfilled in any other part of the site, so for eight weeks virtually no work went on at all.

The first proving of the heating system was afforded by the main office block. After some three weeks, when there had been no trouble, and the calculations of the E. & M. experts were bearing fruit, a sudden uproar arose in the east boiler house. The hot water storage cylinder, upon which two cascades are mounted (in which high pressure steam from the boilers is mixed with the cooled return water from the circulation system), started shuddering and creating a minor earthquake. The whole unit when full weighs some seventeen tons, and is mounted in the top of the building. It was not built to jump about. This phenomenon caused a considerable stir. Fires had to be drawn at once. The designer of the system arrived post-haste from Darmstadt and the D.D.W. and the staff in Bad Oeyhausen showed justifiable anxiety.

This particular design of cascade mixer for steam and hot water had been used in several large installations in Germany, and had up to that time never given any trouble. It was some twelve hours before the system had cooled down sufficiently for the cascades to be removed so that the inside of the apparatus could be examined. When the examination was made, it revealed little that could have accounted for the commotion which had been set up in it. Only a bucketful of black grit and welding spawls from the insides of the pipes was found in the hot-water reservoir and there seemed little to indicate how a recurrence of the trouble could be precluded. It was thought that on light loads, running both cascades at one time, a correct balance had not been maintained between the proportion of steam and water in the mixing. Hereafter, on light loads one of the cascades was cut out and only one employed, and the steam pipe leading into the cascades was modified in shape, so that the mixing of steam and pulverized water might be effected less violently. There has up to now been no recurrence of this phenomenon, though the nervous apprehension it induced was not dispelled for a long time.

By the time the thaw came, in March, 1954, it was obvious to the Engineers that there was no prospect of completing the project ready for a move in July. The C.-in-C. had determined on a move on the 1st of July, and it was only by his Chief Engineer and staff presenting to him the inescapable conditions as they had developed that the move was reluctantly postponed until 1st October. (We on the site would have preferred the 1st December.) In fact the C.-in-C. judged it to a nicety, but we then much doubted that it was possible for essentials to be ready by 1st October. The new date for the move brought even greater effort and co-ordination into play.

The summer of 1954 was again good for the growing of turf. There was constant rainfall the whole season, which made underground work, laying of services, etc., very difficult. By June, most of the heating ducts had been laid, and the sewage and storm water drainage had been established and tested, *but many of the man-holes serving both these systems had not been completed nor had their covers been fixed.* On the 19th June, there was a rain storm of 1.77 in. There were two main results of this, firstly, vast quantities of storm water flowed into the sewage system (which was by then functioning for the service of the Guard Regiment and Camp Staff details), and filled the collecting chamber with more water and rubbish than it could digest. Secondly water got into the heating ducts, where it was rapidly boiled by the pipes at 170° Centigrade. Steam was generated so rapidly that lengths of duct were blown up, and much damage was done. In general all excavations which had not been filled in (and there were a good many) were grievously washed out. Pipes were displaced and sides fell in. It was a bit depressing.

On the night 14th/15th August, 3.4 in. of rain fell in six hours! Due to the minor set-back in June, underground work was by then little nearer completion than in June. The same troubles now reoccurred, but on a more magnificent scale. The sewage collecting chamber was again entirely blocked by debris, storm water backed up into sewage drains, and welled up in torrents into the nearest building. (I suppose it was justice that the building which suffered worst in this respect was the completed R.E. office, in which my own staff was working; at 3 a.m. there was 6 in. of water and sewage and mud in every room.) The sewage collecting system was designed to pump 3,500 cubic metres a day (with a normal diversity factor). In the June storm it coped with a rate of 5,000 cubic metres a day over the storm hours—and in the August storm it pumped, for the hours before it was choked by debris, at a rate corresponding to 9,000 cubic metres a day. This was of course storm water which had trespassed into the foul water system and represents only a fraction of the discharge in the mains, most of which back-filled and burst out of manholes. The heating ducts again suffered considerable damage, several hundred metres being entirely washed out of the ground. Sixteen of the underground calorifier stations, most of which had their delicate electrical control equipment and pump motors by then installed, were filled to the roof with water and mud. The cellars of over fifty houses were similarly inundated to the roof. Many more were less seriously flooded. In Germany various kinds of contractors do not co-ordinate themselves well. The contractors engaged on leading in the service pipes to the houses and underground calorifier stations had done little to bar flood water from rushing from their trenches straight into the buildings.

With the move impending within six weeks, and with many administrative units already on the site, it was discouraging to suffer this crisis. A storm of this magnitude had not been seen by the locals in living memory. I pleaded that we would appreciate further postponement of the move, but this was not granted, and as it proved rightly so. After the deluge followed a week of fine weather, the only sun that was seen the whole of that summer. The tenacity of the German workmen and his grim satisfaction in hard work eventually cleared up the mess in an extraordinarily short space of time.

There were ample illustrations of the difficulty of co-ordinating the various underground activities. My staff was too attenuated (and indeed it was not their duty), to co-ordinate directly the work of the underground contractors competing for the same earth space. I do not think it is unfair to say, in spite of the much vaunted ability of

German planners, that this vital collaboration is not a strong point in German construction work. German Engineers in charge of the various activities were inclined to be parochial in their demands, inconsiderate of the viewpoint of their colleagues, and often at loggerheads. When crises were reached it nearly always devolved on us to call a round-table conference, and metaphorically bang their heads together. In this exercise my S.O.I, Mike Lewis, was particularly able. The consequences of unco-ordinated work by contractors not only retarded general progress, but were in themselves infuriating. Six times in 1954 high tension cables already laid in the ground were cut by drivers of mechanical excavators engaged in opening up trenches for drains or heating ducts. This not only interrupted lights, but stopped work by cutting the power to contractors' machinery. Twice the gas main was similarly cut (it had been made live with gas in order to serve the Guard Regiment and other units living on the site). The possibility of gas line breaks had been foreseen, and a drill existed to cope with the eventuality. It took some time to get the gas people informed, and to have the source of supply turned off at the valve house. By that time a lot of gas had been discharged and more was trickling out of the broken ends, so that on each occasion for some hours all personnel had to be evacuated and all work stopped within 300 metres of the break to avoid the risk of fire.

The water mains were frequently cut. As for drains, it will not be known for a long time how many storm water branch drains have been thus interrupted and now fail to flow as designed into the main confluences!

By German law, any claim for damages on account of the breaking of underground connexions by an excavator can only be brought to the account of the operator himself. We could not punish contractors and they in turn could do no more than sack the operator; but operators are in high demand, as they are in England, and could always get another job immediately. There was, therefore, no effective redress against these "accidents", and with our sense of humour wearing thin in 1954, we were maddened by the phlegmatic attitude shown by the long-suffering German authorities to this recurring nuisance. Nothing would force contractors to resort to hand digging, even when ordered to, in localities where there was danger of excavators cutting other services. In fact no record plans of sufficient accuracy had by then been drawn to enable the F.S.B.A. or contractors to define exactly where services had already been laid.

A final exasperation of this kind occurred when the Bundespost (German G.P.O.) laid their main cables to the telephone exchange. We had given the strictest injunctions that the main cable route should be laid along the northern edge of the site where it would have reached the telephone exchange without any danger to other services. I was mortified therefore one day to see the trench for

Bundespost cables being carved regardless of all obstacles by the shortest route through the very centre of the married quarters area. We frequently progressed backwards when we could ill afford the time.

(*b*) *Main Headquarters Block*

Two-thirds of this building of 2,000 rooms was destined to be for Headquarters, Northern Army Group, and one-third for 2 A.T.A.F. In November, 1953, when the roofs of the building were finished, and much of the interior decoration starting, important changes of mind were made on the security aspect of the building. This is not the place to describe the measures then planned, but in short, another DM.2½ million of work had to be ordered in April as a result of deliberations on security measures. The work consisted mostly of building steel linings into a large number of rooms, the addition of five luggage lifts and shafts for dispatching graded files to the strong rooms below, and a great number of small alterations. Putting a steel lining into a room which already has a functioning radiator heating system and electric lighting is not easy because of communications having to be isolated and ripped out and then re-done after the steel lining is in.

This work would not have ranked as a "difficulty" if we had had longer to plan and execute it, but it was all too near the inescapable 1st of October, when the headquarters were to move.

Army Headquarters moved down between the 1st and 4th October and command passed with the new building on the 4th October as planned, but the attendant headaches were considerable. We had in the original planning foreseen a host of minor alterations which would inevitably be necessary once the Headquarters settled itself in, and to that end we had devised the light partitions capable of easy moving and re-building as has already been described; but for a month while the security measures were being completed and bell systems, doors and partitions were being moved, the Headquarters was not a comfortable place to work in. At the same time some thousands of desks and cabinets and chairs were being installed, while linoleum was being laid in nearly three miles of corridors. All complaints (and there were many) seemed to rise to Chief-of-Staff level and to fall with the acceleration of gravity on our heads. A large crate of glass diffusion shades was dropped while being unloaded from a lorry and 400 were broken, so that 400 officers had a legitimate objection to the lighting installed in their offices, which temporarily lacked this desirable fitment. The master clock of the clock system having been installed in the Signals Office *as directed*, was ordered at a later date to be moved *twice* again. There was rightful annoyance in Headquarters that even the clocks were late, and this small item kept my E. & M. staff uncomfortably chivvied about. It was difficult for us not to regard these incidents as trivial.

There were dozens of similar ones, and each naturally set the telephones of my overworked staff irately buzzing. There are no technical lessons to be learnt from these experiences, except to recognize the inevitability of such occurrences and to bear them.

As might be expected, hundreds of minor snags occurred in the 800 odd houses as soon as they were occupied. The process of taking over fifteen houses a day (after two preliminary examinations of them with the contractors) would have been complicated enough if every item had been perfectly finished. As it was, a list of thirty or forty minor items for every house remained to be rectified. It is difficult to get contractors back to do these little jobs, especially when the same contractors are being pressed to finish off houses which have only reached an earlier stage. The two most serious snags are worth describing, because lessons can be drawn from them.

When the painters and decorators are in, the W.C. pan is generally not yet fixed, and the drainage head on which it will be mounted makes a tempting repository into which a slip-shod workman can tip the carpenters' chips, paper, tins, plaster overspill, and other rubbish. It all falls to the bottom of the drain and as far as the workman is concerned, is satisfactorily disposed of. When the house is taken over and the W.C. plug is pulled, away goes the water just as designed. It is not until the house has been occupied for *several days* that the obstruction in the bottom of the pipe becomes a bung which solidifies and prevents the outflow of successive discharges of the W.C. A week or ten days later the dammed up products rise through the gullies and the house becomes flooded with a most unpleasant influx. *This happened in over sixty houses.* Our hearts ached for the unfortunate occupants, and as far as was humanly possible we sent contractor's men to rip out the drains if necessary and discover what was wrong. The bung was sometimes located in the bottom of the heel rest bend within the house, and sometimes only found by digging up the drains in the garden. These annoying troubles occur in any big project, but more frequently in Germany than elsewhere. There must be some way of preventing them.

The second serious source of trouble in houses was due to the faulty manufacture of water pipes. Out of the first fifty-six houses taken over, thirty-two developed very serious leaks in the hot-water pipes when the hot water had been set going in the system. Sometimes this occurred before occupation, and sometimes not till after the occupation of the house by a family. Every pipe system had been tested as prescribed to two-and-a-half times its working pressure by a cold water hydraulic test. Testing had not disclosed anything more than an occasional weeping joint. When the hot water entered the pipes, however, it was found that many of them were splitting along their longitudinal seam (a certain amount of longitudinally welded pipes in domestic sizes had been stock-piled for the job).

The effect of this failure, particularly if it occurred when the furnished house was locked up pending the arrival of an occupant, was in many cases disastrous. Some of the pipes were in the walls, behind casing, and when they leaked extensively wall plaster and wood block floors were quickly ruined.

To find these conditions rampant in 60 per cent of the first houses handed over at the beginning of the move was upsetting, to say the least of it. Mercifully as the handing-over proceeded, it was found that this trouble occurred only in certain limited contract lots. It was undoubtedly caused by the fact that hot-water pipes of the longitudinally welded type had not been in every case led through sleeves in the walls and their expansion on heating was forceful enough to open faulty welded seams. In the end this trouble was met in less than a hundred of the houses. The consequences of it were very serious, but after the first shock the contractors had gangs standing by to cut off points of failure and repair them before too much damage was done. The moral of this is that all pipes, particularly hot-water pipes, must be led through sleeves and not anchored to the building.

There were a number of cases of deliberate ill intention. Some chimneys were built with bricks blocking the flue so that smoke could not escape. These were discovered when fireplaces were tested. They probably only represented the efforts of one disgruntled workman and they did not inconvenience occupants, for the fault was corrected before houses were handed over.

There is no need to go into the hundreds of ordinary snags, mostly resulting from warping of timber, which beset joinery, doors and windows. There, is however, a lesson in this manifestation and that is that it is almost impossible to get contractors back quickly to put small defects right, and it is essential to have a gang of directly employed labour working systematically through the whole estate in the first month of its occupation. Quantity surveyors and contractual purists deplore this policy, but the need is inescapable in a large project done in a short time. We were fortunate in being able to get the services of about seventy artisans of a German artisan unit.

Stores

By Christmas, 1952, when the spending of money was the primary consideration, a requisition had been placed on the German authorities to stock-pile steel pipes of every kind, roof tiles, sanitary ware, cooking ranges, chain link fence, and other items in large quantities. Over 4,000 tons of pipes of all sizes were included in the stock-pile. This was possible, because by 1952 the remarkable recovery of German industry had already outstripped immediate demands. The total value of materials stock-piled was about DM. 9 millions, which made up a substantial proportion of the payment of DM. 20 million we were able to make by the 1st of January, 1953. The stock-pile of manufactured goods was largely in the suppliers' factories. Only gradually was material of this kind brought into store within call of the site. Some of the piping, as has already been described, was longitudinal welded piping, which only proved itself vulnerable when it was incorporated in work a year and a half later.

If this project had been conducted two years earlier, before the recovery of German industry, or if it had been carried out two years later after the great revival of intensive building in Germany, it is probable that we should have suffered many shortages of ordinary material in the conduct of the work. As it was, it is gratifying to state that there was remarkably little delay through the failure of supply of stores and material.

In the broad specifications which were issued to the German authorities the choice of materials allowed for the carcassing, flooring and roofing of all buildings was very liberal. The purpose of this was to give contractors the option of tendering for a variety of materials within the specification, so that no particular commodity would be drawn upon to the extent of creating a shortage therein. The only memorable shortage occurred in the provision of oak and beech blocks for parquet flooring, which had been specified in the ground floors of all married quarters and in the main rooms of messes and clubs. The quantities required were considerable, but even so we were given assurance at first that there would be no difficulty in the supplying of wood blocks. In the summer of 1954 when the pressure to complete houses became almost more than we could cope with, flooring contractors suddenly announced that their capacity for completing the job on time was falling short by a great extent. In a small measure we relieved the situation by specifiying various alternative types of tiles or indigenous stone floors for the halls of houses and messes and in the end by accepting the failure of some of the parquet contractors and scouring the face of Germany for others to take their place. The German authorities got them just in time. On the whole I don't think we could have been more fortunate than we were in the capacity of German industry to satisfy our demands for materials for so large a project.

We set up sample rooms of fittings and materials of approved specification. These contained every manner of domestic finishing and fitting. Except in respect of protection from frost German plumbing and sanitary design is much inferior to ours. By insisting on adherence to approved samples we avoided taps which squirt outwards and drench the user's torso, and waste pipes which take fifteen minutes to empty the bath. My insistence on English sanitary practice had one lamentable and incurable result: We prefer a "wash-down" water closet, whereas European practice is to install W.Cs. of the "hospital pan" type. German manufacturers agreed to make a "wash-down" pattern at my orders. The result is my "patent non-flushing W.C.", for it is also European practice to flush W.Cs. by a push-button direct off the mains. The combination simply doesn't work. Much time and water are spent in pushing the button with long delayed effect.

The moral appears to be not to interfere with established local practice.

Labour

When the project started it was calculated that the maximum labour force on the peak of the job would be about 15,000 men. Even so, the conditions of unemployment in Germany in 1952 allowed confidence on the part of German and British authorities that sufficient labour would be found. In fact at the peak period of intensity of work in the late summer of 1953, the labour force on the site was only 6,400. We had anticipated allotting contractors areas in which they could erect temporary labour camps on the site. This never occurred, as the surrounding towns and villages were able to absorb the influx of outside labour and only a few key men and watch keepers lived on the site. The rent for a room in the surrounding villages rose from DM. 30 a month to DM. 120. Labour worked overtime at rates which are considerably less than overtime rates in England, and the rent they were prepared to pay for their accommodation is a measure of their eagerness to get work at that time. The only shortage of labour we experienced was in layers of parquet flooring, which further aggravated the trouble I have described in finishing the married quarters.

Only three fatal accidents occurred during the project. In one case, a German labourer engaged on digging a drainage trench some four metres deep was buried by a failure of the shoring. In England, it is the practice to shore excavations by vertical planks laid behind horizontal waling. In Germany the practice is to lay horizontal planks behind vertical baulks. When the planks are laid horizontally the difficulty comes in striking the shoring, and in this case it collapsed and buried the man. The moral appears to be, stick to English practice.

The ever deteriorating temporary electrical supply which ran overhead to supply contractors on site was responsible for the other two fatalities. A German workman trod on the bare end of a live cable in hobnail boots on a wet day and was instantly killed. A gunner in the Light A.A. Regiment, on night patrol, picked up a trailing cable-end which had dropped from one of the temporary overhead poles. My E. & M. staff had frequently drawn the attention of the German authorities to the derelict state of the temporary supply, but in the urgency to catch up on work, such details had not received the attention they should.

The moral is obvious.

Gardens

Each married quarter was provided with a manageable garden surrounded by a fence. Half of this was designed to be seeded to grass, and the remainder to be vegetables and flowers at the will and ability of the occupant. Flowering shrubs, a small hedge and three fruit trees were provided as part of the project in the average garden. The success of this scheme rested upon the proper re-spreading of the top soil over the formation after the excavations for the underground services had been completed and consolidated. I have already described the complications of performing underground services punctually when the above-ground building has started first. In the event, in many localities the trenches for underground work were not properly consolidated after filling, and in many instances a sufficient layer of top soil was not established because the contractors responsible for erecting the fences had gone ahead too early. To ensure that this work was thoroughly done everywhere in 1,000 gardens proved impossible with my small staff. Much difficulty arose in getting garden contractors back to complete their work, and one's sympathy must be with them when it is considered that the confusion did not allow them a clean run on the job. The lesson in this is, that if a housing project is done too quickly, the gardens are bound to suffer.

Conclusion

There has never been a project like this. It has never happened that one Chief Engineer and his staff have been able in the span of one military appointment to help choose the land, plan the site, and see it built, occupied and working. It is a task we have enjoyed and appreciated. I think the main ingredients of success with speed have been (*a*) the delegation of planning and control to a low level, with support by higher authority, (*b*) the ability of German labour to work hard, and (*c*) a first-class staff able to take advantage of this German characteristic. It is not military custom to write an acknowledgment of the individual efforts of one's staff, but they know what they have achieved. In addition to a splendid staff of officers, I was exceptionally well posted with warrant officers and senior N.C.Os.

A notable and unforeseen reinforcement lay in the young National Service officers and men who were posted to me in 1954 when the demand for supervision became urgent. I was given officers in their early twenties who had during their deferment gained qualifications of various kinds in civil engineering. They came with enthusiasm and the nature of the job increased it. The task could only with difficulty have been done without them, and I hope that they will have regarded it as considerable experience for their future in civilian life. (I could not persuade any of them to stay.)

I have not given Baudirektor Schmalbruch and the F.N.B.A. and higher German authorities their full due. If I have made too much of their inherent differences in outlook and method it is because the difficulties of a project provide its interest and instruction. In fact the keenness, tenacity and vigour of German effort, from the drive of the highest executive to the industry of the lowest labourer, was the main force we applied to the building of a complete town in little more than two years. I hope it may again fall to officers of the Corps to conduct a large project in such well favoured circumstances.

(Owing to expense, it was only possible to publish a limited number of photographs in Part I. Two additional photographs showing work rather outside the scope of normal barrack construction are reproduced with this part. They show the well-appointed bar in the Officers' Club and the outside of the Model Room/Theatre.

Acknowledgment is gratefully given to those whose photographs have been published, namely Lieut.-Colonel Lewis, the B.A.O.R. Public Relations Branch, *Soldier*, and N.A.A.F.I..)

ICH DIEN

By Lieut.-Colonel J. V. P. Braganza, Indian Engineers

Garur is an unimaginative little Kumaoni village whose only claim to importance is its forming the dual roadhead into the interior of Garhwal and Almora. A brisk trade in tea, potatoes and salt seems to be the main means of livelihood for the otherwise famished peasants. Every day, and at almost every hour, one can hear the tinkle and movement of the pony packs as the caravans plod carefully over the low foothills.

It was in one such caravan that Gupta and I arrived at Garur after our hurried trip to the Pindari Glacier. Although we had risen early to walk the fifteen miles from Bageshwar to Garur it was no small disappointment to find that the last bus for the rail terminus of Kathgodam had left. Fortunately we had an able host in old Bachi Ram, a pensioner of the Garhwal Regiment, who looked after the small *fauji serai* at Garur. Bachi Ram cleared everyone and everything off the first floor of the building, offering us spare blankets and a hurricane lamp. He even volunteered to get us a meal. Both Gupta and I had by now accustomed ourselves to the cooking of Lance-Naik Digar Singh, so we declined the offer with suitable expressions of reluctance.

While our man-of-all-work set about his chores we decided to spend the daylight hours looking at the village and its people. We soon parted company, as I was bent on climbing a near-by hill in order to photograph the massif of Trisul, which towers up so tremendously as to appear only a few hours' trek from Garur. A well-defined pathway aided my passage up the hill. Half an hour's brisk climb and I had reached the top. As I had anticipated the higher slopes had been cleared of pines; unattended tea bushes were growing wildly on the stepped inclines, but on the plateau the crops had been carefully planted around the ruins of a large stone building.

I glanced quickly at Trisul, towards which the clouds were drifting from the west. Hurriedly I set up my camera and made the exposures. I was so absorbed in my task that it was some time before I became aware that a man had approached and sat watching me intently from a near-by mound.

"Ram Ram," I said. "What is your name?"

"Mohan Singh."

"Are these your fields, Mohan Singh?"

"No, Sahib," came the answer. "They are the property of Randall Sahib. I am only his servant."

"Doesn't he look after the tea estate?" I queried.

"Not now." The response was almost abrupt.

"Where is the sahib?" I asked.

"There!" replied Mohan Singh, pointing over his shoulder at the ruined house.

"Can I meet him?"

"Yes, come along." And Mohan Singh rising quickly strode off with the short rapid steps of the pahari. I followed him, my curiosity aroused. Who was this Randall Sahib who possessed this neglected property? Why did he live in a ruined bungalow? He must be a character worth meeting.

Mohan Singh had disappeared behind the few remaining walls of the house. I clambered over the large stones of the verandah. The roof and timbers had long since been blown away by storms or carried off by the villagers. The hall was covered with grass and weeds. The floor slabs had been forced apart by the growth of plants. I hesitated: should I go in farther? Where was this chap Randall? Perhaps Mohan Singh was calling him from some innermost room of the place. Minutes seemed to tick by . . . Impatiently I called:

"Is anyone there?"

Suddenly, and as silently as he had disappeared, Mohan Singh showed himself in a doorway on the left.

"This way, please, Sahib." He pointed into the dark recess.

I walked in . . .

At first I could see little because of the gloom. Behind me a match scraped as Mohan Singh lit a candle. He held it aloft and pointed towards the far end of the room.

"Randall Sahib!" he said.

Suddenly the air seemed to have gone quite damp and cold. A draught from the rear caught the flame of the candle and held it flickering for an interminable instant. I felt a qualm of fear. Was I the victim of a misplaced sense of humour, or was I with a madman?

Then just as quickly a feeling of quiet reassurance came over me and I walked forward with a vague sense of awe towards what was clearly the grave of this unknown.

It was a simple brick plinth crudely plastered. The central rectangular portion had been packed with earth and a carefully-tended grass patch bore testimony to the fact that this at least was one spot in the wilderness which was not neglected. At the head was a roughly carved log cross which had been daubed black. Below it was a wooden board on which was scrawled in Hindi:

E. A. RANDALL

6th November 1946

He rests among the hills he loved

As I stood staring through the candlelight at this unusual sight, a gust of wind extinguished the flame, leaving the two of us in the dark. A storm appeared imminent.

"Must be getting back," I murmured more to myself than to my companion. Turning I blundered out of the ruins helped by the glare of the occasional lightning shafts and the frantic efforts of Mohan Singh to relight the candle. The first drops of rain were already falling as I ran down the path to Garur.

That evening before a warm fire and the remains of our one bottle of rum I questioned Bachi Ram about the history of the lonely tomb and its custodian. There was not much I could extract from him. Randall had been a tea planter who had served in the Army during World War II. He had returned to his plantation after VJ Day, but had died a year later of tuberculosis. Mohan Singh was an orphan from Danpur, whom Randall and his wife had looked after and employed as a general help on the tea estate. When Randall had been called up in 1939 Mohan Singh had joined the same regiment and had accompanied his master as a batman to Burma, where they were captured by the Japanese. While they were prisoners Mrs. Randall had died in Ranikhet hospital after a long-drawn-out illness. The property had been kept going, although at no profit, by planter friends. In 1945, shortly after VJ Day, Randall and Mohan Singh returned as released prisoners. Despite the heavy setbacks of a losing business and indifferent health, the two worked hard to restore their fortunes. The effort had proved too much for the older man; he had succumbed to the illness he had contracted as a prisoner of war. Until the end Mohan Singh had tended him.

"But alas, poor Mohan Singh!" sighed Bachi Ram. "The strain has affected him. He just will not leave the place although he is now alone. None of the villagers dare go near the estate. They think it is haunted!"

* * * * *

Our bus to Kathgodam left early in the morning. I had collected my things on a front seat and was settling myself, when Gupta came up from a crowd which had collected round Lance-Naik Digar Singh.

"What is it?" I asked.

"There is a man here, sir," he said, "who insists that Digar Singh give him the Group badge from his cap."

"Whatever for?"

"I don't really know, sir. He was talking in Kumaoni."

Meanwhile Digar Singh had pushed his way to the bus followed by a number of hangers-on. He was brushing aside the explanations of one man in particular. I immediately recognized Mohan Singh.

"What is the trouble, Mohan Singh?" I asked.

"May I have this Taj, Sahib?" he requested, pointing to the badge on Digar Singh's beret.

"I'm afraid you can't. That is a part of my jawan's uniform. He cannot give it away."

"Please, Sahib," he pleaded. "I would very much like to have one. You see, Randall Sahib and I also used to wear this badge a long time ago."

"What! Were you Bengal Sappers?" I was completely taken aback.

Gupta and I exchanged looks.

"All right, Digar Singh, give him the badge" I ordered.

Without a word, Mohan Singh took the badge and stared at it.

The driver of the bus impatiently sounded his horn. The conductor jumped in and slammed the door. Painfully the vehicle jerked itself up the cobbled street. This was the end of a delightful holiday. I glanced back as we rounded the corner. Mohan Singh stood in the middle of the street with his hands cupped elbowing off the curious spectators . . .

* * * * *

When I reached Roorkee I found a pile of work awaiting me. For two or three weeks I was not able to search up the particulars on Randall. I had, however, mentioned him to the Group Adjutant over supper in the Mess. A few days later I was pleasantly surprised to get a call from the "A" office.

"Mark here, sir. You remember you asked if I could find the details on a Captain Randall. I've jotted these down from the papers we have been able to find. I'm sending them across now."

A messenger brought the single sheet of foolscap with its terse sentences.

> RANDALL, EDWARD ARTHUR. Born 1904. Winchester and Cambridge. University blue Cricket and Soccer. Pass Economics and History. Joined Colonial Service 1929. Resigned 1931 to take up tea planting in Almora. O.C.T.U. Roorkee. Commissioned 19th Oct., 1939 and posted to 3 Field Company. Proceeded overseas June, 1941. Awarded M.C. in Jan., 1942. Captured by the Japanese in Mar., 1942. Released from enemy custody by 12 Army in Apr., 1945. Reverted to civilian status 25th May, 1945. Awarded M.B.E. and Mentioned in Dispatches for outstanding fortitude and devotion to fellow prisoners.

* * * * *

Two years elapsed before I could again visit the hills. I had spent the first year in Central India and the second in the south. Neither afforded me the opportunity for trekking and photography which the Himalayas had so generously given. It was, therefore, with much enthusiasm at the prospect of a trek and the chance of meeting many ex-servicemen, that I planned to attend the Bageshwar Mela held in January each year. This time there was no question of missing the bus. I actually chose to spend an evening at Garur so as to renew my acquaintanceship with Mohan Singh. Bachi Ram, however, shook his head forebodingly.

"I'm afraid you may not be able to meet Mohan Singh," he warned. "For the past three months he has come less and less to the village and chases away anyone who attempts to walk over the estate. We think he has gone quite mad. I believe we have not seen him now for a week, and no one dare go up to his shack."

Laughingly I chided him about his fears and set off along the familiar path. The going was far more difficult than it had been on my previous visit. Clearly the only living creatures which used it were cattle in search of better grazing. Secondary growth covered the path and in the steeper portions the monsoon rains had washed away all traces of the cobbles. The creepers thinned out as I ascended higher. Near the ruined house I noticed the plots of crops and vegetables had disappeared. The ground was rapidly weeding over. It must have been some time since Mohan Singh had collected his small harvest. And yet—this was his sole means of sustenance.

"Mohan Singh!" I shouted, and again, "Mohan Singh!"

There was no human answer, but the echo from across the valley rolled back eerily. I strode across the bulging flagstones, and through the door on the left into the chamber where Randall's grave was. My torch flashed across the room. What was that huddled in front of the brickwork? I approached cautiously, and then, when I recognized it was Mohan Singh, at almost a run.

I gently shook the prostrate body.

"Wake up, Mohan Singh!" I called.

There was no response. I turned him over, and then started back in astonishment—Mohan Singh was dead. The faithful servant had watched his charge to the last and had gone to join his master. I took another look at the poor fellow. How long was it since he had expired? And then my eye caught a glint of metal which shone from the log cross at the head of Randall's grave. It was the Group badge which we had given Mohan Singh. Somehow he had fixed it to the wood and had kept it polished. So he could not have died later than yesterday, more likely today, only a matter of hours before I had arrived.

I took from my pocket a similar badge which I had intended to present to Mohan Singh, and placed it on his chest. How delighted he would have been to receive it. Something moved me unconsciously to the attention and a salute to the dead.

I made my way out of the ruins to the accompaniment of rolls of thunder. As I reached the edge of the clearing I paused to look back at the house. There it stood forlorn and dilapidated, yet in some mysterious way so peaceful . . .

Without warning of any kind a searing flash hit the ruined mansion. I found myself thrown to the ground. The whole clearing seemed to be aflame. For an instant I was dazzled and numb; then the instinct for preservation forced me to stagger down the path, tripping over the roots and bushes, but placing me out of the zone where the lightning had struck. The entire hilltop was ablaze—truly a magnificent pyre for Mohan Singh.

I watched the flames spreading. The villagers would have seen it by now and might perhaps be anxious about me. Already I could hear shouts and discern movement at the foot of the hill. I pulled myself together and stumbled down to meet them as the rain descended in torrents. There was no sense of sadness or horror left; instead a feeling of immense pride welled up, for the words of the Chinese leader Sun Su seemed to reach across twenty-five centuries to make a burning epitaph for the two I had left on the hill:

> "Regard your soldiers as your children and they will follow you into the deepest valley; look on them as your beloved sons and they will stand by you even unto death."

THE ARAB LEGION ENGINEERS

By Lieut.-Colonel J. Constant, R.E.

IN view of the recent events in Jordan leading to the regrettable dismissal of Lieut.-General Sir John Glubb and the majority of the British officers of the Arab Legion, readers of the *R.E. Journal* may be interested to hear how the Engineers of the Legion progressed since the early days described in the March, 1954, issue.

The writer's experiences in the Legion started inauspiciously as I was posted from Egypt in July, 1951, and was on my way by ship from Suez when we heard the news of King Abdulla's assassination. This came as a great shock to the whole of Jordan as I found from the moment I landed at Aqaba and drove up via Amman to Zerka, where I was to live.

At the time of my arrival, there was an Independent Field Squadron commanded by a British major, with seven Arab officers, three of whom had been to Sandhurst and the S.M.E. There were no other Arab sappers from which reinforcements of officers and men could be drafted to expand this Squadron; no school or training regiment in which new officers and men could be given Engineer training. As and when new Cadet officers joined us, we sent them in pairs to join the Y.O. courses at the S.M.E. in U.K., if their English was up to standard.

Later we sent each of the three senior Arab officers to Chatham on Field Engineering courses. The S.M.E. training was a great help to this handful of officers who were fortunate enough to get it. The remainder of the officers and all the N.C.Os. and men had to learn in the unit.

As the 1st Field Squadron, and the others when they formed, were always occupied in exercises and operations, we decided at once to create a separate training wing. This consisted initially of a British Captain and two W.Os. (one Fieldworks and one Mechanical) but later grew to a complete Training Squadron.

The planned expansion of the Arab Legion was based on Brigade Groups, and during 1951 we were saddled with the difficulty of trying to equip and train two Independent Field Squadrons on these lines. The brigades, to which they belonged, found them useful for many tasks which had neither operational nor training value. Fortunately, this soon became apparent to the authorities, and in 1952 we were permitted to expand and train as a regiment. By concentrating on one base camp with all our barrack huts, training grounds, magazines, stores, workshops, museums, etc., we were able to spread the supervision by the very few British and experienced Arabs to the maximum advantage.

There were always shortages of every sort: weapons, signals, vehicles, explosives, engineer stores, on the one hand; huts, accommodation stores, clothing, stationery, fuel, on the other. But far and away the worst shortage was in trained personnel, particularly officers. There were no Engineer pamphlets, nor could these be created by simple translation, because at that time no two Arabs could agree on the appropriate technical glossary. The same trouble occurred over stores demands and the complicated system of Arab accounting.

I have laboured our difficulties above, but they were by no means insurmountable. There was a great deal of good-will on all sides, and common sense usually prevailed.

In spite of his enormous responsibilities, not only to the Legion and the Police, but also as adviser to the Jordan Royal Family and Government, Glubb Pasha himself took a personal interest in our progress and visited us every month or so. Not only did he help us to overcome our difficulties, but, as a former Sapper himself, he was full of new ideas, which stimulated the officers and men, all of whom had great faith in him.

We were also helped by the British Army in every way. General Sir Brian Roberston, then C.-in-C., M.E.L.F., paid us two visits; and, as he was also a Sapper, he quickly saw our difficulties, and arranged through his Chief Engineer, for us to borrow much engineer equipment from the British stocks in Egypt. This was at a time, when our demands on U.K. were taking about a year to materialize, unless lost in the somewhat tortuous official channels.

The equipment loaned from M.E.L.F. stocks not only made Engineer training possible, it also had a great morale effect on all ranks, as it proved to us (and, incidentally, to the other Arms) that our training was important.

Eighteen months after our expansion began we had formed a complete divisional Field Engineer Regiment (including Signals and L.A.D.), organized on the lines of the British H.E. We were still short of some technical equipment and vehicles, mostly in the Field Park Squadron, but the essentials were there. Only our officer position was parlous; we were deficient of three majors, sixteen captains and thirteen lieutenants, all of these positions being filled by officer cadets with only one or two years service! Everyone was very keen and these young officers learnt quickly.

We divided our time about equally into four parts:—

(*a*) Individual Military Training.
(*b*) Individual Engineer Training.
(*c*) Engineer exercises and projects.
(*d*) Collective exercises and/or operations.

In the end we had excellent facilities for both types of individual training at the Engineer Base Camp. A parade ground big enough for the whole regiment. An assault course, 25-yds. miniature range, sten range, 100-yds. range for rifle and L.M.G., and a grenade throwing area. A driver-training area, to improve new drivers before taking over their vehicles. Training rooms wired for signaller training and tests. A trade training workshop. A completely dug and revetted position for a company in defence to practise manning and reliefs. Water points and camp structures. A demolition ground. Various bridging grounds with full size exhibits. A minelaying ground and a separate mine clearance training ground, over which a simple spectators-stand looked out. Here visitors could watch a demonstration of a Field Troop coming into action from its vehicles and coming under simulated infantry and artillery fire as it carried out a breaching operation. Near by was a large area for training all plant operators.

Each winter a bridging camp was held in the Jordan valley, for each squadron in turn. This combined necessary training with operational security, as bad weather could block the routes from Amman to the Israel frontier.

In spring and autumn many exercises were held in the desert, and the engineer tasks were usually minefields and water supply. My impression was that most Arabs are less adaptable to desert living than the British. They certainly did not experience the genuine love of the desert, which so many British have.

In October, 1953, we had been able to train as an Engineer Regiment for the whole summer, and we were taking part in a Divisional exercise which had an interesting Engineer aspect. For the first time the Plant Troop of the Field Park Squadron was out as a whole, with the task in one night of dozing protective holes, into which the essential vehicles of a Brigade H.Q. could be moved and concealed before dawn.

In spite of striking several layers of rock, the Plant Troop were successful and the Brigade H.Q. moved in on time.

While this desert exercise was going on, an event occurred from which the Legion never really recovered its balance.

The little frontier incidents, to which both Arab and Jew were accustomed, were suddenly overshadowed by the Israeli Army's formal military attack on an Arab frontier village Qibya, about halfway between Jerusalem and Tel Aviv. It was conducted by a battalion, using their heavy weapons in support, and resulted in a Jewish company breaching the village defence-wire with Bangalore Torpedoes and blowing up thirty-seven buildings with concussion charges. Over one hundred Arab civilians (men, women and children) were killed or wounded.

This assault had a most violent moral effect on the Arab countries as a whole, as well as on all of us in Jordan.

My Regiment had returned to camp after a week on the desert exercise and the married men had just gone home for the weekend, when a Divisional "O" group was summoned and we first learned of the outrage. By the time divisional orders were complete, it was 9 p.m. (on a Thursday night—the equivalent of Saturday night here).

The Division mobilized that night in the dark with men continually trickling back dubiously from their homes. Before dawn my first troop moved off armed and equipped for war, and throughout that morning others were following to take up positions for blocking communications in rear of a frontier over 200 miles in length.

Our detachments were never bigger than a troop, and in most cases only a section. Squadron Commanders joined their affiliated Brigade H.Qs. to give engineer advice. We prepared and charged over 100 demolitions, some under the eyes of the Israeli infantry.

We made thirteen light aircraft strips, mostly in mountains, and laid a number of minefields.

During this intense activity, we suffered from the lack of any Corps and Army Sappers. We had for some time appreciated this deficiency in our order of battle; but now, from necessity, we formed a Base Engineer Regt. (changed to "group" after I left) to support us. This was a cross between a Corps Field Park Squadron and a Workshop and Park Squadron. In addition it included our Training Squadron and an Engineer Boys' Squadron, which had recently formed.

After Qibya, the Engineers never concentrated completely again. We always had at least one Field Squadron supporting the troops on the frontier. The political background was never so happy and secure, and there were numerous "flaps", which played havoc with planned programmes of training.

The Engineers were now in great demand, and, at last, had both the training and the stores to meet their tasks. Our visitors increased in number and included King Hussein, who appeared to take a keen and detailed interest in everything he saw. We were happy when he arrived wearing the Engineer flash on the sleeves of his service dress. He admired our Regimental Colour, as he inspected the Guard of Honour. He took the controls of an Angledozer. He fired a demolition, and we were relieved it did *not* fail. During this item, I persuaded him to wear a steel helmet for safety and had arranged a choice of three sizes of brand new helmets. He put on the biggest, but somewhat dubiously, as it sat on the top of his head and he told me his size in hats was 8!

The visit finished with lunch in the Officers' Mess; and, during coffee just before leaving, he autographed his copy of the printed programme with the words "To the Royal Engineers of the Arab Legion of Jordan, Hussein", so we were delighted at becoming the **Arab Legion Royal Engineers.**

Photo 1.—King Hussein, with his Minister of Defence, discussing one of the Arab Legion Engineer officers' vehicles. (A Land Rover with desert equipment, L.M.G. and W.S. 62.)

By permission of Arab Legion

Photo 2.—King Hussein watching an Engineer demonstration with his Minister of Defence and Glubb Pasha. The glasses contain coca-cola!

By permission of Arab Legion

Arab Legion Enginers 1,2

Photo 1.—View from Anoyira up the valley towards Kissousa showing terraced vine-yards. Backfilled pipe trench in centre foreground.

A pipeline in mountainous country 1

A PIPELINE IN MOUNTAINOUS COUNTRY

By Major B. H. Grant, R.E.

Introduction

I HAVE divided this account of how a field engineer regiment built a pipeline into two parts—non-technical and technical. I am not competent to write of the reasons for the original design and any expressed are mere assumptions based on common sense.

Part I—Non-Technical

Cause, Reason, Aim

In 1951 it was decided to move G.H.Q. Middle East Land Forces from the Suez Canal Zone to Cyprus. A site was chosen at Episkopi Forest and an adequate source of water was discovered in a spring near the tiny village of Kissousa in the mountains ten miles to the north.

As far as the very inaccurate records and unreliable local memory indicated there was here a supply of over a million gallons a day, ample to cover the estimated requirements of 600,000 gallons a day and allow for future expansion.

The Kissousa spring is 1,800 odd feet above sea level and flows freely at ground level. The source, therefore, has the advantage over all other possible sources that no pumping is required, with its evils of machinery, fuel and labour costs, and risk of breakdown.

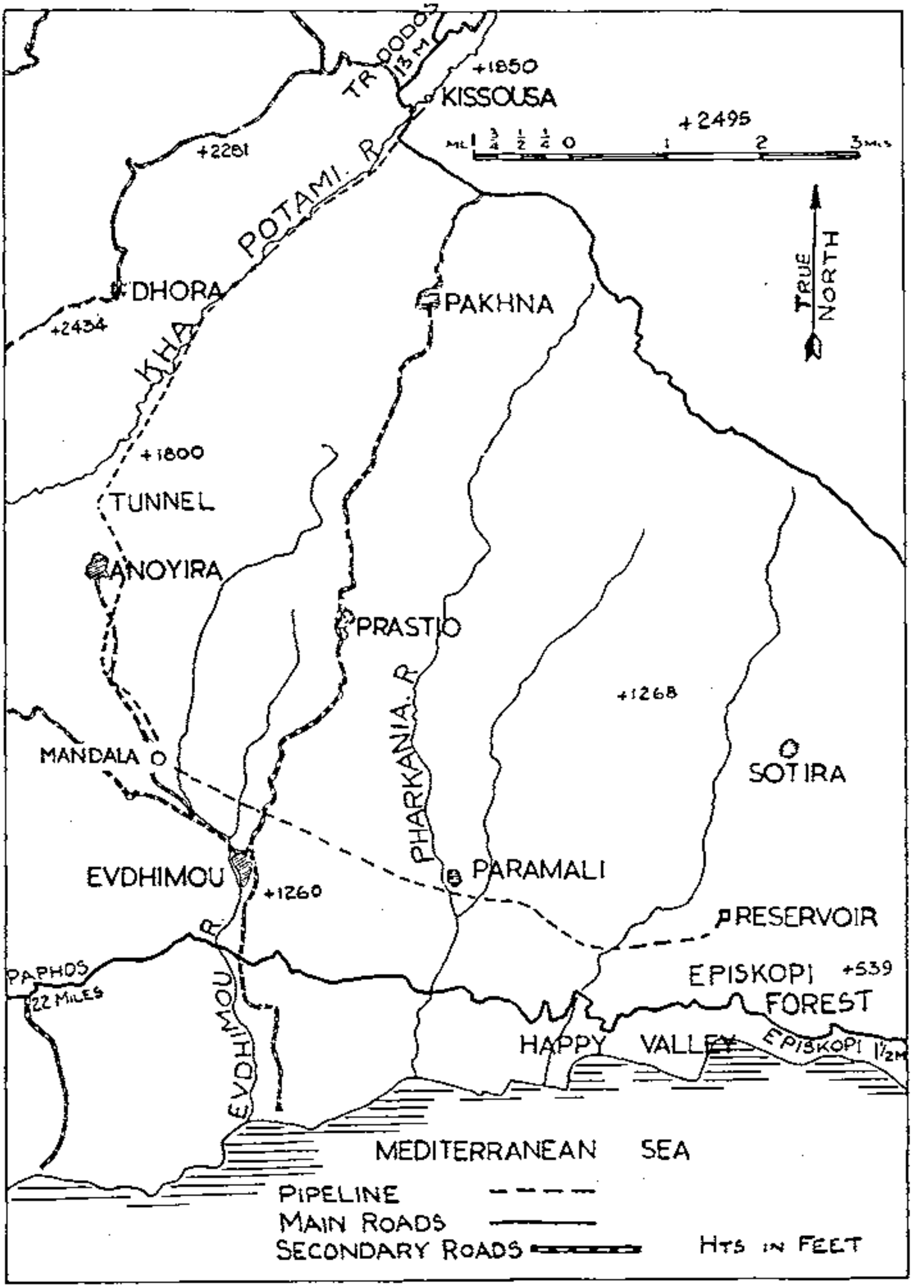
The Kissousa spring possessed another advantage as it was not used for irrigation purposes. In the fertile coastal plains there is plenty of water to be obtained from boreholes. The pumping, however, of the large quantity required for the Episkopi cantonment would have so lowered the water level that many of the existing schemes of irrigation might have been jeopardized. The Cyprus Government naturally took a very serious view of this prospect.

It was therefore decided to supply the Episkopi cantonment from the Kissousa spring, conveying the water from spring to reservoir by a route which would obviate pumping.

The Gradual Appearance of the Field Engineer Regiment

To reduce the cost, and because the project was supposed not to be an attractive one to a civilian contractor, it was decided to construct the pipeline using military labour. A Field Squadron was chosen for the work. The Squadron moved to Cyprus from the Canal Zone in January, 1953. It established itself in Polemidhia Camp, three miles from Limassol.

February and March were occupied by preparation, planning and reconnaissance by the officers, and troop training by the men. From April to July the Squadron was engaged in the construction of about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MEDITERRANEAN SEA
PIPELINE
MAIN ROADS
SECONDARY ROADS
HTS IN FEET

six-and-a-half miles of access tracks. These were only made fair weather tracks, but the work was very slow because of the poor condition of the plant and the lack of spares.

It was decided that the Squadron had to be based more centrally on the pipeline and a new camp site was picked near the little village of Anoyira. Access to Anoyira was not easy, a three tonner taking forty minutes to cover the last six miles of twisting climbing road to the village. It was less comfortable and farther from the flesh-pots of Limassol. But the advantages of living on top of the work made the new camp essential. Money was allotted and construction took place from July to October. At the same time a start was made with excavation near the source at Kissousa. This was the only place where deep excavation was necessary and a 20-ft. cut into rock was made using pneumatic picks and explosives.

Two interruptions occurred during this period. In August there was the earthquake in Greece. The Field Squadron embarked in 36 hours, but the ship was slow and the Royal Navy had completed first aid by the time the Squadron got there. In September the earthquake was at Paphos. The squadron was early on the spot and stayed for a fortnight dealing with the dangerous ruins and helping the population pitch tents produced by the army for the Cyprus Government.

Anoyira was just fit for full occupation in October and the Squadron moved in. Excavation was begun on the pipe trench southwards from Anoyira, using an Allen Parsons Trencher and local Cypriot labour. In November a Barber Greene Trencher arrived and was put to work two miles farther south. The bigger machine digging a trench two feet wide was a great help in accommodating in the trench the 38-ft. lengths of pipe supplied.

This pipe was uncoated and should not last as long as the bitumen coated pipe laid elsewhere in the line. The treatment plant in the Canal Zone, however, had had a fire and was temporarily out of action. We could not afford to wait any longer for the pipe and laid this untreated stock which happened to be in Cyprus. These long lengths weighed over 1,000 lb. and were difficult to handle using Cypriot labour. They were brought from Famagusta, nineteen at a time on a specially adapted Tasker trailer. Unloaded by hand the pipe was lifted into the trench using a Caterpillar D 6 tractor fitted with a side boom crane. We had two of these cranes, both on an obsolete model of tractor. We were extremely lucky that spares were never needed.

One troop of the Squadron was engaged all November and December in completing the camp. On 18th December we were honoured by a visit of the C.-in-C., General Sir Charles Keightley. The same day we had our only fall of snow at Anoyira that winter and we hoped he was duly impressed by our hardiness.

On 23rd December heavy and continuous rain began. The use of machines became impossible and the work slowed. Access was only possible to the small portion of the pipeline which ran alongside established tracks. One troop quickly discovered the erosive power of heavy rainfall. They backfilled some 200 yards of pipe trench one afternoon and when they went there next morning the whole of the backfill had been washed out, and they were hard put to it to remember whether they had backfilled that stretch or not.

An attempt was made to produce a programme for the completion of the pipeline by one squadron. Accuracy was impossible, approximation was unlikely, but if there is a programme, however nonsensical it may be, at least there is something to amend as progress teaches, and something to indicate the timing of stores' orders. Why was no exact programme possible? Firstly, the drawings and specification had not yet been issued and the full extent of the work was not known. Secondly, the geological formations are so confused that it was impossible to predict either at what depth rock would be found or how hard the rock would be. The forecast of time, labour and plant for excavation was therefore bound to be a shot in the dark. Thirdly, no information was available as to the work capabilities of the villagers. Six feet of trench 2 ft. wide by 3 ft. deep in earth was reckoned as a reasonable task for one man in an eight-hour day. Experience has shown that it takes two men to do so much in a day.

The programme showed one squadron, which was at higher establishment, completing the pipeline by the end of 1954. However, early progress showed this to be far too optimistic and the Squadron also began to run down to lower establishment. The chart of anticipated water requirements showed that in January, 1955, the temporary supply would not cope with the demand. A firm completion date of 31st December, 1954, was laid down and it was decided to move Regimental H.Q., a second Field Squadron and the Field Park Squadron to Polemidhia and employ them, as well as the original Field Squadron, on the pipeline. They arrived in late February, 1954.

By April, the second Field Squadron had joined the first Squadron on the pipeline and the Field Park Squadron had taken over the responsibility for stores, plant and workshops. As experience was gained progress improved, until in August it became clear that the pipeline should be completed by the given date. The original Field Squadron had by now become just a collection of pipeline constructors and was not fit for any other military task. The second Squadron therefore replaced the original Squadron at Anoyira early in September, and the latter put one troop into a month's training, keeping the other on the pipeline. The troops changed over in late October and a new task appeared.

Either the Kissousa spring always was unreliable or else the

Paphos earthquake had affected it. But new records showed that for five months in the year the supply was less than the 600,000 gallons a day required. Some boreholes had been put down in Happy Valley for the temporary water supply. A third Field Squadron, who had joined the Regiment in Polemidhia in July, did some test pumping of these holes. These tests showed there was an ample supply there and a scheme was proposed for the installation of submersible pumps in four boreholes, operated automatically by floats in the main reservoir. A new pipeline 1½ miles long from the boreholes to the main pipeline had therefore to be constructed.

Water first flowed down the pipeline from Kissousa to Mandala on 23rd November and from Mandala to Episkopi on 31st December, 1954. On that day the branch pipeline was 50 per cent complete. Tidying, marking and maintenance continued after the pipeline was put into operation and it was not until March, 1955, that the Regiment withdrew the last squadron.

A Field Engineer Regiment on a Works Task

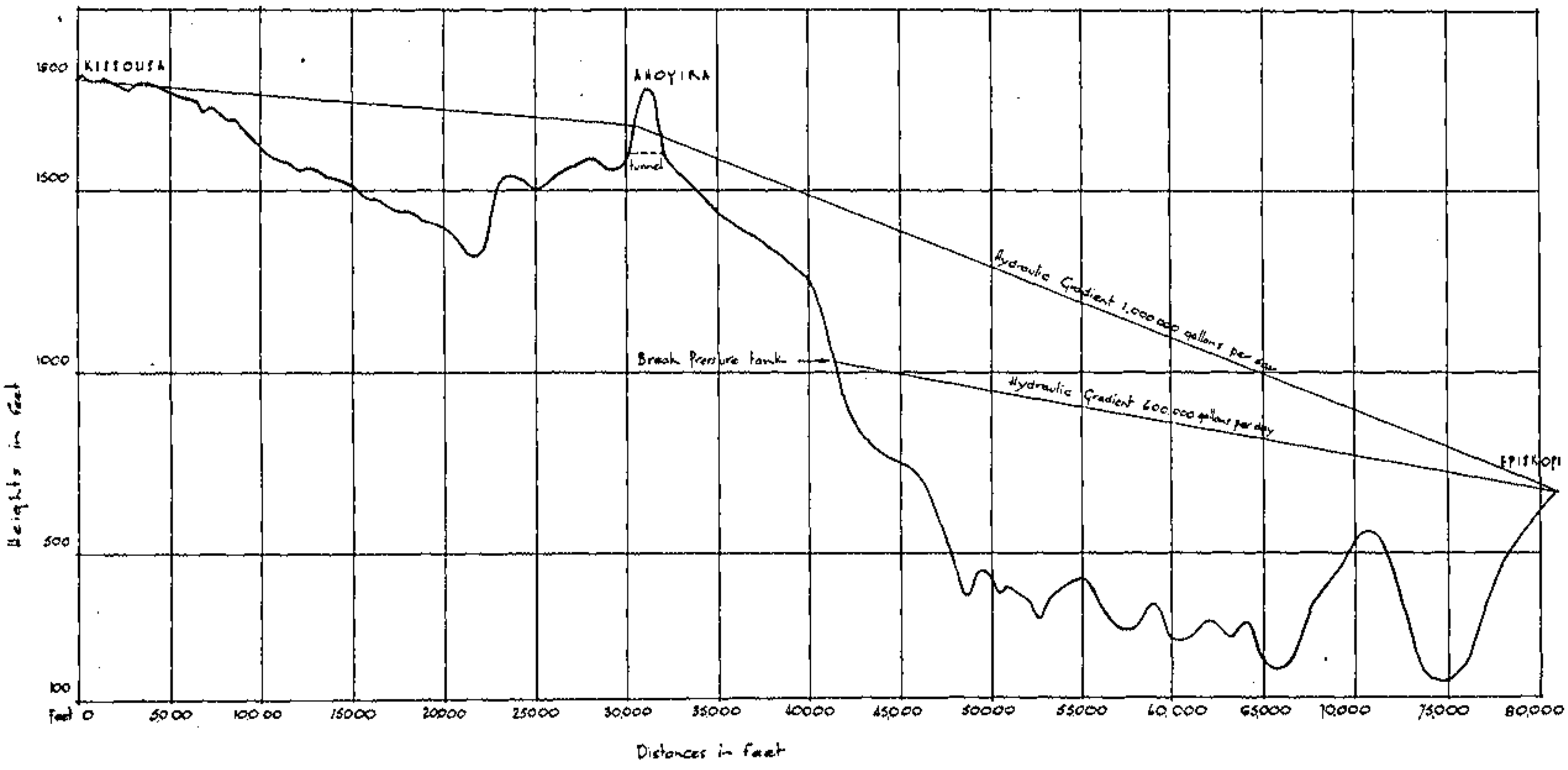
With an underposted lower establishment it was found that three troops per squadron could only provide construction parties that were too small to work economically. The two Field Squadrons were therefore reduced to two troops each, each troop being made responsible for all the tasks for a certain section of pipeline. Where possible experts in one operation were kept on that operation. But the need to shift emphasis from one operation to another as difficulties cropped up and the ever-changing population, made this impossible to apply rigidly.

The third Field Squadron was employed on other tasks in Cyprus and was not available for the pipeline. It required, however, the backing of the Field Park Squadron and the latter tended to become overloaded, but it was kept up to full establishment and strict priorities laid down.

The C.O. of the Regiment was also Garrison Commander, Limassol. Besides the pipeline he was responsible for the works tasks being undertaken by the third Field Squadron and many other things not relevant here. It was therefore necessary to appoint a Regimental Project Officer who could concentrate his whole attention on the pipeline and whose duty was liaison with the C.R.E. Episkopi and his staff, co-ordination of the work of the two Field Squadrons and, where necessary, the allotment of priorities for the pipeline work of the Field Park Squadron. The O.C. of the first Field Squadron was appointed to this job since he had been longest on the pipeline and had the fullest knowledge of it.

When one Field Squadron only was on the job, C.R.E. Episkopi exercised supervision just as if the Squadron were contractors. When the Regiment arrived it was made responsible for its own supervision. C.R.E. Episkopi continued to keep the construction account,

PIPELINE PROFILE



all stores were ordered through him and he engaged and paid all the civilian labourers, of whom we employed at the peak of effort about 500.

Non-Technical Conclusions

My experience on this pipeline has led me to the conclusion that a field engineer regiment should seldom be employed on a Major Works Service in peacetime for longer than three months. My reasons are:—

(*a*) If the regiment is still to have the form of a regiment on completion of its task it must preserve the regimental organization. The regimental establishment is not suited to a works task and cannot be adapted to it without abandoning the regimental organization.

(*b*) All regiments are underposted in peacetime because of the national manpower allocation. A regiment on a works task, with its squadrons separated from R.H.Q. and the troops separated from squadrons, requires a much higher maintenance manpower than that provided in the establishment and cannot afford to let the maintenance men get below strength. The underposting therefore occurs exclusively in the working numbers. The rate of turnover of reinforcements also has its impact. It is spasmodic and can run as high as 50 per cent of a squadron strength in a month.

(*c*) Individual training must go on. Otherwise the regiment soon finds itself destitute of drivers, clerks, medical orderlies, signallers and other specialists. Running these courses and providing the students is a heavy drain on manpower. This drain again falls exclusively on the working numbers, with the result that these become too few for economical working. A field squadron can seldom keep more than thirty working numbers continuously in the field.

(*d*) A regiment is liable to be distracted by such affairs as Administrative Inspections and a visit from the U.M.I. team whilst the project is in full flight and project factors have control.

My conclusion is not affected by personal preference. I enjoyed every minute of my time on the pipeline and the men enjoyed it too.

When a contractor gets a contract it is his own responsibility to arrange for a supply of everything he needs. When a regiment does the same thing it has to look to "Q" Staff to provide it with the extra supplies of transport, clothing, equipment and accommodation which it will need for the job. Engineer Staffs remember the Engineer Stores, but are inclined to forget Ordnance Stores. At the same time as arrangements are made with "G" Staff for the employment of the regiment, arrangements must be made with "Q" Staff to supply the backing. There must be foresight here as it takes a long time to move the stores—tyres, boots rubber knee, or stoves oil heating—into a depot from which a regiment may draw them.

Part II—Technical

Design and Specification

The simplest way to get from Kissousa to Episkopi is straight down the main road. Just south of Kissousa, however, there is a ridge over which the water would have to be pumped, or through which a tunnel would have to be driven. Six miles farther along the ridge to the S.E., near the village of Anoyira, the Water Supply and Irrigation Department had driven a tunnel 1,700 ft. long through the ridge to take a 3-in. pipe carrying the village water supply. The tunnel is 200 ft. lower than the spring at Kissousa.

Access along the valley between Kissousa and Anoyira was difficult because of the ground and objections by villagers. But the use of the Anoyira tunnel avoids pumping, to avoid which it was decided to make use of the Kissousa spring. So the pipeline was routed through the Anoyira Tunnel and across nine miles of relatively easy country the other side.

The original intention was to take 1 million gallons per day from the spring and the pipe was designed to pass this. The little drop in height between Kissousa and Anoyira requires the use of a 10-in. pipe. After that, with the greater head available, 8-in. pipe was big enough. Later, after construction had begun and the pipe was being shipped from the Canal Zone, it was discovered, in view of the state of the pipe, it was not advisable to make use of the full head available. It was doubtful if the pipe would stand 1,000 ft. working head and measures were taken to reduce this head to a maximum of 650 ft. This was done by putting in a break pressure tank at the 1,050 ft. contour and the elimination of all 8 in. sluice valves thereafter. Lack of sluice valves ensured that neither surge pressures nor static pressures could ever be applied in error, but only the working head made up of the static head less friction loss.

The introduction of the break pressure tank reduces the head available so that now only 600,000 gallons per day can flow through the 8-in. pipeline. A by-pass has been fitted to the break pressure tank so that in emergency, when risks are justified, the full pressure may be applied, and the output of the line raised again to the original figure.

Maximum temperature variation in Cyprus for the empty pipe in the sun is about 100° F. To avoid having to provide expansion joints the pipe has been buried. Where it passes through cultivated land 2 ft. cover has been given. Where it crosses roads the cover has been increased to 3 ft. When rock has been met the pipe is buried little more than its own diameter below the rock surface.

At the highest point of each rise is a 2-in. tee on which there is a ball operated air release valve. At the lowest point of each dip is a 6-in. tee and sluice valve for the scouring out of sediment introduced during construction or from the spring.

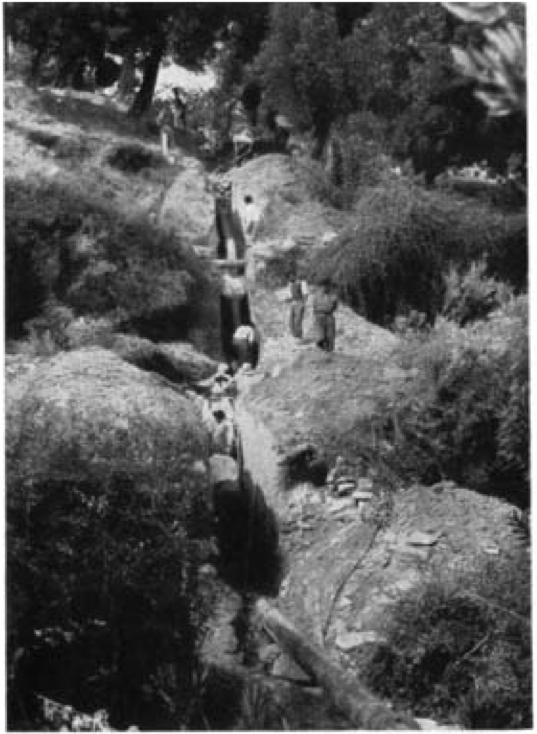


Photo 2.—A gang of local labourers backfilling pipe trench.

Photo 3.—A steel tubular pier resting on a flood resisting foundation.

A pipeline in mountainous country 2 & 3

Photo 4.—The break pressure tank overflowing at 1.2 million gallons per day. The water flowed down a cascade, along a rocky gully for 100 yards.

Photo 5.—Water from break pressure tank falling over a 50 ft. precipice, 100 yds. from the tank.

A pipeline in mountainous country 4 & 5

The pipe is mostly in 20-ft. lengths. The joints between these lengths have been made with Viking Johnson couplings. In these couplings the joint is made by forcing a rubber ring of wedge section between the pipe and the internally chamfered sleeve. The manufacturers state that a bend of 6 deg. can be made at each joint. But because of the high pressures involved and the difficult conditions of work a maximum bend of 3 deg. was specified, except in certain stretches where pressure was low and the extra allowance was desirable, as in the Anoyira tunnel. The longitudinal strength of a Johnson coupling is nil, neglecting friction. The uneven coating of the pipe had to be scraped and wire brushed off the end 4 in. to provide a good seating for the rubber sealing ring. To prevent subsequent corrosion the ends were painted with one coat of bitumen paint. A section of the joint is shown on page 136.

On a 3 deg. bend in an 8-in. pipe at a test pressure of 1,300 ft. head there is a sideways thrust of 0.6 tons. With the backfill rammed around the pipe this thrust can be tolerated. There are many places on the pipeline where the change of direction exceeds 3 deg. per 20 ft., or where to make it so gradual would mean excessive rock excavation. Here a special bend had to be installed. The sideways thrust in similar circumstances on a 22½ deg. bend is nearly 5 tons, and backfill alone will not hold it. A mass concrete anchorage was specified for all specials.

However hard it is rammed the backfill is unlikely to reach the compaction of the undisturbed soil. The backfilled trench will then be the first to suffer erosion during surface run-off in the wet season. The erosion forms a shallow trench and the effect is much aggravated. To lessen this erosion, walls have been built across the trench, keyed into the undisturbed soil at the sides. Concrete was originally specified but stones were so plentiful locally that the specification was changed to random rubble masonry set in cement mortar. The spacing of the walls is dependent on the gradient of the pipe.

Where the pipe crosses a gorge it is carried on piers. The piers have mass concrete founds from bedrock to 1 ft. above top flood level. Masonry is built on the founds and capped with a concrete pipe saddle. The pipe is strapped into the saddle and is carried high enough above flood level to be clear of all debris. There are three exceptions, two of which are masonry and the third is of welded tubular steel construction with a timber saddle. All the piers were built by a contractor.

Access tracks were originally specified as permanent all weather tracks for maintenance purposes. These were later deleted from the project and the only access tracks to be made were the temporary ones required for construction purposes.

Construction Problems

The rock varied greatly in hardness. As the hardness increased the following methods were used for its excavation:—

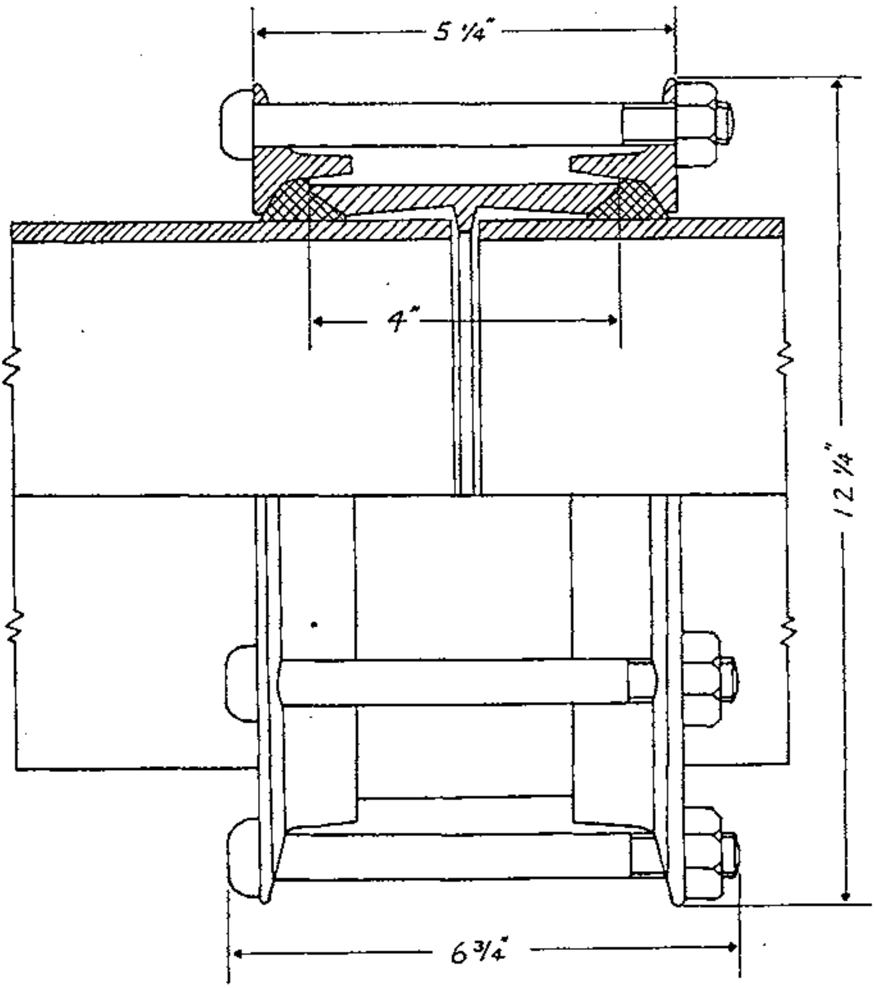
(*a*) Hand Pick.
(*b*) Pneumatic Pick.
(*c*) Concrete Breaker.
(*d*) Borehole Charges.

Where the rock was weathered and broken a single tine rooter was effective. In several places, too, there was a hard stratum of rock overlaying a soft, and the rooter would break up the top, leaving the soft underlay to be picked out. Isolated boulders were often dealt with by the use of a sledge-hammer, the movement of plant not being practical or economical.

It was expected that where the excavation was deeper than about four feet revetment or shoring of the trench would be necessary, particularly in wet weather. This fortunately was not needed, the trench walls standing up to 12 ft. deep, even in the heaviest rain.

Excavation between Kissousa and Anoyira was entirely by hand. Between Anoyira and Episkopi machines were used for about 70 per cent of the work. The Barber Greene was the more useful machine, digging a 2-ft. wide trench which permitted digging errors and allowed room to do the jointing. The Allen Parsons had the advantage of being the smaller machine and passing the trees without doing much damage. On the other hand the Barber Greene would dig through soft rock and the roots of trees, whereas the Allen Parsons could not. In general, excavation in the hardest material was found preferable to the use of specials at sudden changes of slope. The amount of excavation could be mitigated by the use of 10 ft. lengths of pipe, but the use of specials involved heavy concreting. In one sector the amount of concreting necessary amounted to 100 tons to the mile and the cost of imported aggregate at £10 to the ton at site.

The steep country and lack of access between Kissousa and Anoyira made stringing a problem on its own. Some fair weather jeep tracks were made, the intention being to tow a pipe-carrying sulky. In all except one place these tracks were improved to the bare essentials to allow the passage of a three-ton 4 × 4 truck, which could deliver five pipes at a time, and one track was used by a ten-ton tipper carrying special long lengths of pipe for river crossings. The remaining track was beyond improvement, but was successfully used by Fordson Industrial Tractors towing sulkies with two pipes loaded. On this trip the Fordson consumed a gallon of petrol to a mile covered, but survived conditions for which it was never designed. A stretch of one mile was only accessible by a footpath and the pipe, weighing 850 lb., was carried by gangs of labourers or wheeled on



HALF SECTION OF 8 INCH VIKING JOHNSON COUPLING.

Not To Scale.

special trolleys manufactured by the Field Park Squadron. A total of about fifty miles of access tracks were constructed.

Access to the 8-in. pipe sector was easy and the pipe stringing was done from the transport which drove along the line. Over 20-ft. lengths of pipe were handled with a Caterpillar D 6 fitted with a Trackson side boom crane, those under 20 ft. by hand.

An interesting problem was the stringing of pipe in the Anoyira tunnel. This tunnel is 1,700 ft. long and looks as if it was specified to be 3 ft. 6 in. high by 2 ft. wide. For long stretches inside, however, it is 3 ft. 2 in. by 1 ft. 6 in. and not easy for a big man to pass along. It has been driven entirely through rock and is unlined. It passes two faults in the rock which allow plenty of water to get in whenever it rains outside. Cramped space and wet made working conditions bad. The tunnel had been driven from each end and from the bottoms of five shafts. The separate sections did not meet exactly and awkward S bends in the tunnel are the result. The existing pipe was 3-in. steel screwed and socketed.

Many schemes were produced for the stringing of 8-in. pipe through the tunnel. Rails, trolleys, skids and sledges were the means of carriage and most schemes included a rope and winch with a more or less complicated signalling system for communications. The Water Supply and Irrigation Department would not allow the bottoms of the shafts to be opened out, so that it was not possible to lower the 20 ft. lengths of pipe down a shaft and get them round the corner. Even with the rope passing down the 200 ft. deep centre shaft, its length would be inconvenient and would not go on the drum of available winches. The best scheme was the anchoring of a compressed air winch at the bottom of the centre shaft using it as a capstan, carrying the slack end of the rope to the other end of the tunnel and hauling a pipe in from each end alternately, protecting the ends and the coating with a sledge.

In the end the pipe was strung using carrying teams of sappers specially selected for shortness and slimness and lack of claustrophobia. The job was done by task work in two weeks and the teams had two long week-ends. One of the sappers said that it was such hard work walking along the tunnel at all that the extra labour of carrying a 440-lb. pipe between four men was hardly noticeable. The tunnel was lit by 40-watt lamps every 50 ft., fed by a 50-volt transformer located at ground level by the mouth of the centre shaft. It was considered dangerous to use a higher voltage than 50 in such wet conditions without special wiring and fittings, the expense of which was not justified. The transformer was borrowed from the R.A.F., the 230-volt supply coming from the camp generator.

The available labour all came from the villagers through whose land the pipe line passes. Other labour would have required transport or accommodation and would not have been allowed to work.

The sense of ownership among the villagers of Cyprus is very strong and quick punishment is dealt out to all who transgress. A stranger who walks in the fields may even suffer bodily harm. A sheep stealer was shot in Anoyira during the time of the Field Squadron's encampment there. This rough justice is discouraged and prosecutions occur. But in the genuine case of property protection the penalty is extremely light. One of the conditions of the wayleave obtained for the pipeline was that the owner would work in his own fields. The gangs, therefore, had to be carefully organized to ensure that no village worked except on its own fields and the owners of the fields were in the gangs if they wished it. As the pipe trench approached the territory of the next village a few of its inhabitants would be standing on the boundary with menacing looks daring the existing gangs to dig one shovelful in the next village.

When our trenchers first appeared they caused consternation. The farmer had considered picks and shovels when he gave us wayleave and had not pictured these clanking horrors. Considerable persuasion was necessary at first, but after they had seen that the trenchers made less mess of their fields than a gang of diggers we had no further trouble. A Cypriot Plant Operator, however, had his life threatened and we had to put a Sapper on the machine; but that was because he came from the wrong village, not because of the machine.

One or two cases arose where a villager was a Communist. Wayleave was difficult and sometimes the pipe had to be realigned. The half dozen Communists in Anoyira tried to cause trouble by inserting hostile articles in the Communist Greek Press. We were on good terms with both the Greek and Turkish Mukhtars and were able to get contradictory articles put in the rest of the Cyprus Press. The Turkish Mukhtar was the head labourer of one of our gangs, and the Greek Mukhtar ran a profitable refreshment kiosk on his own land adjacent to the camp.

Hydraulic testing of the pipeline was a problem that was difficult to solve satisfactorily. It was specified that the line had to hold twice the working pressure for ten minutes without measurable loss of head. Getting the pipe full of water and then raising it to test pressure were neither as easy as they first appeared; 82,000 ft. of pipe had to be tested in sections. If the sections were too small too many tests would have to be made and too many joints would remain untested. If the test sections were too long then it took a long time to get up to test pressure, if a leak occurred a lot of water was lost in emptying the section to rectify the fault, and control was difficult. After several trials, 2,000 ft. was selected as optimum length.

Since the pipeline was not built in sequence from Kissousa owing to the factors of weather and terrain, it was not possible to use that spring to supply water for testing until very late in the construction programme. C.R.E. Episkopi lent the regiment a 3-ton water tanker. Using this truck it was possible to put in the 4,400 gallons in a 2,000 ft. length of 8 in. pipe in nine trips. This was practicable provided that the turn round was not more than about three-quarters of an hour, and that the ground was suitable for a 4 × 2 three tonner. The C.R.E. had a storage tank for his temporary water supply, from which it was possible to pump to the reservoir end of the pipeline.

The vehicle method is all right in good weather, with good access, when the test is proceeding downhill. For it is only necessary to fill the first section and then pass the water from one section to another using 2-in. armoured hose and topping up from the tanker. But at the bottom of the hill the water must be let out and a fresh start made at the next hill crest. The method is thus slow in summer and impossible in winter when the truck gets bogged down in the wet; it is heartbreaking where the pipe has been badly laid.

Using the pipeline to supply the water either from the spring or the reservoir removed these disadvantages. It was not, however, easy to transfer water from one section to another. The static heads involved go up to about 600 ft., which is greater than armoured hose will stand, especially if it has been in store for long. Sections must then be joined with steel pipe and a fresh plumbing job done for each section. This is wasteful of time, skilled labour and 2-in. pipe.

The high pressure pump supplied for testing was a boiler test pump with a swept volume of 2.2 cu. in. Maximum test head was 1,300 ft., an average head was 600 ft. To raise 200 ft. of 10-in. pipe full of water to a head of 600 ft. it is necessary to inject 2,070 cu. in. to account for the elasticity of the pipe and the compressibility of the water. So that strokes of the order of 1,000 should have been sufficient. In practice the strokes were ten to twenty times as much. Moreover, the head reached and the strokes of the pump bore no straight line relationship, but a curve growing steeper as the head increased. It was expected that some air would be in the pipe, but the result indicated a great deal more. The greatest care taken in filling failed to eliminate the air. It was therefore found essential to raise the pressure as high as possible, using a pump with a large delivery, and then transfer to the little high pressure test pump when the rate of change of head with pump strokes was reasonable. The only portable pumps to be had were No. 4 pumping sets. Coupling these pumps in series it was possible to obtain 400 ft. head at zero delivery, but only at the expense of broken glands. As the state of the pump glands got worse the maximum pressure reached decreased and the waste of water increased.

The best answer to this problem was an engine driven, high-head pump with a reasonable output. In November, 1954, a 3-cylinder ram pump of U.S. origin designed for oil pipe lines and driven by a 150 h.p. engine was provided. It was skid mounted and was used to test the last 40,000 ft. in two lengths of 20,000 ft. At the normal governed speed of the engine the pressure rose from atmospheric to test pressure in about one minute. The clutch between engine and pump was then thrown out and pressure held by a non-return valve fitted in the pump delivery. The rams produced a pulsating effect, but this was not large enough to be serious and was partly absorbed by the deflection of the 15-ton anchorage.

Miscellaneous Technical Points

The vineyard walls are retaining walls for the terraces. The latter are constructed to prevent soil erosion when cultivation is carried out on steep slopes. On its way from Kissousa to Anoyira tunnel the pipeline passes through terraced vineyards built on the steep sides of the valley. Many vineyard walls had to be breached and the owners were most anxious lest a sudden thunderstorm should drain off the vineyard into the ravine. Compensation was paid to the owner for each vine uprooted. But what compensates for the loss of a vineyard, vines, soil and all? In the event, the worst never happened. Gaps in the walls were kept as small as possible and were repaired before the rain came.

We were distressed early on by reports that we had laid and jointed pipes with angles of more than 3 deg. at the couplings. Greater care and independent checks were instituted but the bad laying reports still arrived. One spring morning as the day was warming up, a troop sergeant stood by the pipeline where it negotiated a bend using the allowance of each joint. As he watched he could see one joint moving sideways and the bend growing until it exceeded the allowed 3 deg. What was happening was that during the evening the line contracted, straightening out each joint slightly, and during the morning expansion put all the bend back into one joint. After this we backfilled over each pipe as soon as it was laid and had no more trouble.

The tolerances stated by the manufacturers of the couplings for the external diameter of the pipe are plus $\frac{1}{16}$ and minus $\frac{1}{64}$ of an inch. Any ovality or dents occurring in the end 4 in. of the pipe will put it outside these limits. About one third of all pipe reaching the site was damaged at the ends. This meant a greater load on the available men and equipment for cutting off the ends than had been anticipated. Every gas cutting set on the island was employed and special planning was necessary to ensure an adequate supply of oxygen and acetylene.

The 10-in. pipe was supplied in two sizes—10½ in. and 10¾ in. outside diameter. The 8 in. was supplied with 8½ in. and 8⅝ in. outside diameter. The thinner pipe was specified for places where pressure is low. Couplers were supplied to match these four sizes. The differences between the two sizes in each group are so small that they are not readily detected in the field. Though external diameter may be correct the internal diameter often was not, so that a check of the thickness only was a most unreliable guide. A few cases did arise of 8⅝ in. couplings being put on 8½ in. pipe. It was not discovered until the pipe came to be tested and the resulting leaks caused annoying delays. Where a stretch of 8½ in. pipe joined a stretch of 8⅝ in., either a special piece of 8⅝ in. pipe turned down to 8½ in. at one end was used, or an 8½ in. coupling bored out to 8⅝ in. at one side.

A few joints made early on in the job had to be undone because of a minor change in the specification. On examination the rubber jointing rings were seen to be partly eaten away. After brushing the pipe ends clean they were protected from corrosion by a coat of bitumen paint. Each laying and jointing party had a man a few pipes in advance of it doing this work. The paint was still wet when the joint was made and it is believed that the light petroleum fractions used to cut back the bitumen were dissolving the rubber of the rings. the manufacturer supplies special rings for use with petrol and oils; the joints we used were of water quality. To prevent this happening again a quick drying bitumen paint was used and the paint was dry by the time the joint was made.

However much the bolts of the couplings were tightened it was always possible to give the nuts another turn after twelve hours. This may have been due to the finite viscosity of the bitumen allowing the rubber ring to creep slowly along the pipe under the stress imposed by the bolts. At any rate it was considered wise to tighten down the bolts at least three times in 36 hrs. before encasing the joint in concrete. It was always necessary, of course, to tighten the bolts evenly, as if one were tightening down a cylinder head.

The plant used, being from the Chief Engineer's pool, was of ordinary commercial pattern. The air compressors and concrete mixers were furnished with the small iron wheels so commonly heard rattling along England's metalled roads behind the contractor's lorry. In the hills of Cyprus such a mounting was inconvenient. The buffeting over the rock did the plant no good and in soft ground it often had to be winched along. When, later, compressors were issued mounted on a pair of large pneumatic tyred wheels, they were always used in preference to the others because of their incomparably greater mobility.

When using a trencher to dig a trench along a side-long slope, an angle dozer must be sent in advance of the trencher to cut a level track. If this is not done the bucket chain goes down crookedly and the trench is dug with an overhanging wall. On both Allen Parsons and Barber Greene the bucket chain trails behind the machine. When the boom is lowered, therefore, the bucket chain acts so as to prevent the machine from tipping forward. The steepest hill down which the Barber Greene was used had a slope of 1 in 2½, and the machine showed no signs of instability. As a precaution the winch rope of a Hyster winch mounted on a D 8 angle dozer was hooked to the top of the frame of the Barber Greene to act as a preventer. But the rope never had to be used and remained slack throughout the digging of the slope.

A sum of money was provided for the adaption of military vehicles and the hire of civilian ones. The only civilian vehicles available, however, were 4 × 2 trucks, some of which were tippers. In the wet season a 4 × 4 vehicle was essential off the main roads, and at certain places during the dry season where the steepness of the track and the looseness of the surface made four-wheel drive a necessity. Much of the time the transport was carrying men about the job or hanging about waiting for an emergency. In neither case was the civilian vehicle suitable, since it was not licensed for the carriage of passengers, and it was so expensive that for economy it had to be kept working 100 per cent of its hired time. It did come in useful in good weather for the carriage of aggregate from the beach to the site.

Technical Conclusions

There is nothing in the construction of a pipeline which cannot be tackled by a field unit. It calls, however, for great attention to detail, good organization and the training of men in the rudiments of trades other than their own. It requires patience and persistence to ensure that joints are made so that they do not leak under pressure. It needs strict discipline to ensure that tools and other objects are not left inside the pipe and that the open ends of the pipe are properly plugged so that animate and inanimate objects do not get inside.

Acknowledgements

I commanded the original Field Squadron from 21st November, 1953, so that, try as I would, this account has been written from that viewpoint. I would like to make it quite clear that the second Field Squadron, from the time it arrived, had an equal share of the site work and we both received invaluable support from the Field Park Squadron.

I acknowledge with thanks the help I have received from the staff of C.R.E. Episkopi over the early history and design of the pipeline. To Major A. H. W. Sandes, R.E., I am grateful for the story of the work of the Field Squadron before 21st November, 1953.

BRIDGING EQUIPMENT IN THE FIELD AS IT AFFECTS THE R.A.S.C.

By Lieut.-Colonel B. L. Franklin, R.A.S.C.

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THE aim of this article is to describe as briefly as possible firstly the main types of bridging equipment and the methods of its carriage by the R.A.S.C. and secondly, to explain the method of delivery of bridging equipment and the control of its transport in the field.

General Principles

Bridging equipment is an engineer store and therefore its supply, handling and storage is an engineer responsibility, as is also its control. The Engineers are responsible for forecasting requirements and rates of supply, and demand accordingly through engineer channels. They obtain a forecast of the routes and rates of advance from the "G" staff in order to allocate the equipment to formations or units. The "Q" staff arrange for the movement of the equipment and the provision of transport and labour. The procedure is the same at every formation level.

The carriage of bridging equipment by road is a R.A.S.C. responsibility which is shared by both specialist and non-specialist transport units. The specialist bridging companies are highly trained and equipped for the carriage of bridge stores forward to the actual bridging site. The movement of bridging stores at the port, within the base area, and forward by road to the Army dump, usually at the advanced engineer stores regiment, is the task of normal G.T. companies, and bridge companies must never be used in this rôle.

TYPES OF BRIDGES IN USE AND TRANSPORT REQUIRED

Dry Bridges

There are two types of dry bridges at present in use. They are as follows:—

Extra Wide Bailey Bridge (E.W.B.B.)
Heavy Girder Bridge (H.G.B.)

The E.W.B.B. will in due course be replaced entirely by the H.G.B.

The E.W.B.B was developed from the Standard Widened Bailey Bridge (S.W.B.B.) on the introduction of wider vehicles, pending the development of the H.G.B.

For the transport of E.W.B.B. normal 3-ton vehicles without wheelboxes are used. The equipment is made up into parcels and bound together with steel tape. Each parcel weighs about 34 cwt. for convenience of handling by crane. There are six standard truck loads for carrying E.W.B.B.

The basic transport organization for the carriage of E.W.B.B. is based on the establishment of a Bailey Bridge Platoon Type "A" R.A.S.C. In general, one platoon carries sufficient equipment for the construction of 100 ft. of Class 80 E.W.B.B.

The H.G.B. type of bridge is designed for Class 100 traffic and has a standard roadway width of 18 ft. 10 in. This compares very favourably with the E.W.B.B., which can only be constructed to carry up to Class 80 traffic and has a roadway width of only 13 ft. 9½ in.

There are twelve standard truck loads for carrying H.G.B.

For handling purposes lesser components are parcelled with steel tape and the larger components are provided with lifting eyes for slinging.

With the exception of the specialist tractors and trailers for the carriage of raft stores the majority of other loads should be portable on the standard post-war range 3-ton cargo trucks without wheelboxes. Vehicles carrying launching or deck loads must be fitted with bolsters and rear spreaders. These are engineer stores and are fitted by the Engineers during loading, and returned to Engineers on conclusion of a lift.

Vehicles carrying panel, chord reinforcement, and balance beam loads, must have their sides and tailboards removed, although it is possible that in the future 3-ton vehicles without sides and tailboards will be made available.

Although vehicle loads for this bridge have been made standard and a table is laid down for the numbers and types of loads required to construct bridges of various types, no standard platoon loading has yet been published.

The longest length of a H.G.B. bridge that can be carried by a platoon is a 100-ft. span.

Wet Bridging

At present, for wet bridging, Class 80 or Class 30 Extra Wide Bailey Pontoon Bridge (E.W.B.P.B.) and the Folding Boat Equipment (F.B.E.) are used.

The Class 80 will in due course be replaced by the Heavy Assault Floating Bridge (H.A.F.B.), and the Class 30 (E.W.P.B.B.) and the F.B.E. by the Class 30 Light Assault Floating Bridge (L.A.F.B.).

The E.W.B.P.B. follows the lines of the original Bailey Pontoon Bridge. It consists of a landing bay at each bank and floating bays in the middle which are connected to the landing bays by end floating bays.

The standard vehicle loads of the E.W.B.P.B. are based on normal 3-ton G.S. vehicles without wheelboxes. The equipment, with the exception of pontoon loads, is made up into parcels and bound with steel tape. This is done either at Engineer Stores Base Depot or before arrival in the theatre.

The organization of transport for E.W.B.P.B. is based on three types of platoons for the R.A.S.C. Bridge Company as follows:—

End of Bridge Platoon

This platoon carries enough equipment for the end of a Class 80 bridge; i.e. one ten-pier landing bay and one 51 ft. 6 in. end floating bay.

Floating Bay Platoon

This platoon carries sufficient equipment for the floating portion of the bridge, i.e. two 52 ft. Class 80 floating bays.

Raft Platoon

This platoon carries equipment for one 80-ton raft or two 30-ton rafts.

One other wet bridge used is the Folding Boat Equipment Bridge. This is a Class 10 bridge and in due course will be replaced by the Class 30 Light Assault Floating Bridge (L.A.F.B.).

F.B.E. Platoon

The organization of transport for this bridge is based on a F.B.E. Platoon of a R.A.S.C. Bridge Company. It has four sections, each carrying sufficient equipment to construct a 120-ft. span bridge.

Rafting

There are at present two sets of equipment used for rafting. Firstly the Class 50/60 Raft which is to be replaced in due course by the Heavy Ferry, and secondly the Class 12 Close Support Raft (C.S.R.) which will be replaced by rafts from the L.A.F.B. equipment.

Class 50/60 Raft

The organization of transport for this raft is based on the Class 50/60 Raft Platoon of the R.A.S.C. Bridge Company. The platoon has four sections each of five Matadors and trailers all loaded identically. Each section carries sufficient equipment to construct one Class 60 raft.

This platoon may be modified to five sections each of four Matadors and trailers. Each section will then carry sufficient equipment to construct one Class 50 raft.

Class 12 Close Support Raft (C.S.R.)

The organization of transport for this raft is based on the C.S.R. Platoon of the R.A.S.C. Bridge Company. This platoon has four sections of seven trucks each. Each section is loaded identically and carries sufficient equipment to construct one Class 12 raft.

Chain of Supply of Bridging in a Theatre

At Base

Here the main requirements will be to maintain sufficient bridging equipment to build up and supply forward the stocks required by the communication zone and armies. Normally it will be held in bulk by the Engineer Stores Base Depots. Tactical loading of equipment will be unnecessary. Vehicle loading will usually be in bulk for economy in transport.

Army

In the forward areas bridging requirements will be subject to rapid variation due to changes in tactical situations and enemy action. The speed of the operations will always be vital factors in meeting the changing demands. It is therefore essential, particularly during mobile operations, for one R.E. officer to control the supply and transport of bridging equipment to ensure speed and flexibility. This is the responsibility of the C.E. Army, who is responsible for sub-allotting the resources, including transport, allotted to him by the "G" and "Q" staffs. Army should have sufficient transport available so that additional vehicles should not have to be allotted by Division or Corps "Q" Staffs to their Engineer Commanders.

The method of supply will be "forward supply", i.e. the senior engineer commander of each formation is responsible for delivering to subordinate formations and to engineer troops under his command.

Forward of the Communication Zone, terminal bridging dumps will be established by Army and Corps Engineers. These must be kept stocked by C.E. Army and moved forward as the advance proceeds. These dumps may be either on the ground, loaded in lorries, or a mixture of both. Because of the atomic threat the present policy is to have not more than 200 tons of stores in any one place. Therefore the Corps or Army dump may cover a wide area. Furthermore, some bridging equipment may be required at very short notice; this is held on wheels at a Corps or Army Bridge Point.

As Corps move forward, the C.C.R.E. will open new bridge dumps as far forward as possible and either empty the old ones or hand them over to Army. Army will carry direct to the most advanced Corps bridge dumps. Similarly the Army bridge point will move forward as required.

Some equipment is allotted to divisions and this is normally held in lorries with the Field Park Squadron. This must be reduced to the minimum for the particular operation. Speed and economy of supply can best be achieved by opening new Corps dumps as far forward as possible as the advance proceeds, thereby reducing the turn-round of vehicles supplying the divisions.

Transport retained by the C.E. Army will be controlled by a C.R.A.S.C. who is placed under command of the C.E. for that purpose. With this transport the C.E. will ferry the equipment forward from the Army dump to maintain the necessary stocks in the Corps dumps, and also provide equipment on wheels for Army bridge points. The C.E. will be provided with additional signal resources in order to maintain direct communications with his C.R.A.S.C., bridge dumps and bridge points. The importance of adequate and rapid signal communications both line and wireless cannot be overstressed. The wireless sets must be sufficiently powerful to cover a distance of up to fifty miles.

Corps

The C.C.R.E., with transport, labour, and equipment provided for him by Army, will arrange for initial allotments of these resources to divisions as the situation requires. He is responsible for the whole system for supplying bridging equipment within his Corps; and in practice retains the bulk of his resources under his own command. He supplies the equipment forward tactically loaded in vehicles from his dumps to the divisional or engineer group bridge point. This bridge is operated by the field park squadron of the division or the engineer group.

Bridging transport is then moved forward from the bridge point to a marshalling harbour as near to the actual bridging site as possible, and thereafter, vehicles are phased forward as required, often individually to the site.

R.A.S.C. Bridge Companies are army troops and are allotted to the C.C.R.E. as required for a specific bridging operation. If the allocation of R.A.S.C. Bridge Companies warrants it, a H.Q., R.A.S.C. will also be allotted for command and control.

An R.A.S.C. officer from the Bridge Column/Company will invariably be attached to the C.C.R.E's. H.Q. for liaison duties, but it is wrong for the C.R.A.S.C. or Company Commander to divorce himself from his column or company for the liaison task.

The R.A.S.C. resources in any bridging operation are severely strained, since in addition to the normal administration of the transport units, R.A.S.C. are required to staff the bridge points and provide liaison officers with the C.C.R.E. and at times with individual regiments.

Once the bridging transport is forward of the R.A.S.C. company location, it is liable to be redeployed and reloaded. Consequently the administration of the R.A.S.C. Platoon becomes difficult since sections may be widely dispersed.

At this stage it is well to stress the need for the prompt return of all empty bridging vehicles to the bridging dump for reloading. The number of empty vehicles should be kept to an absolute minimum at all times in order to ensure that the C.C.R.E. always has the maximum resources available. It is here that the engineer planning staff at Corps can considerably lighten the R.A.S.C. load. If accurate anticipation of future commitments can be made, the returning empty vehicles can be loaded accordingly and considerable time and labour avoided at a later date in adjusting loaded vehicles.

Practical Hints for R.A.S.C. Officers Involved in the Movement of Bridging in the Forward Areas

In the last war there were many bridging operations but the lessons learnt have been lost sight of due to many reasons. As a result of various exercises the following practical hints may be of use to R.A.S.C. officers.

Nothing Abnormal

From an R.A.S.C. officer's point of view the supply of bridging equipment is an operation and control of transport problem. There should be no departure from the normal R.A.S.C. practice, and in some ways, it is simpler than normal supply of other commodities in that we are only concerned with one arm of the service—namely the engineers and their equipment.

Importance of Correct Loading

There is, however, the added complication of correct loading. Probably in no other transport unit in the R.A.S.C. is correct loading so important.

Not only must loads be correctly secured but it is essential that a composite load is complete. One small item missed from a load of bridging equipment might well hold up the construction of a whole bridge. It therefore follows that a bridge operation starts at the loading stage. It is at the loading stage that the R.E. troop plays its important part. This sub unit of the R.A.S.C. bridge company is responsible for identification of stores, the correct stowage of the loads, and technical liaison with the R.E. unit for whom the load is being carried.

Control of Loading at Engineer Dumps

One of the biggest difficulties is to preserve the R.A.S.C. "brick" system and thereby facilitate control. The engineers have tactical standard loads which in the main conform to the R.A.S.C. platoon and section organization. However, as the tactical situation varies so does the loading of the vehicles, and loads tend to be improvised according to regiments' requirements. This can cause the disruption of transport companies and even platoons. For a limited period of training the effects may not be fully felt, but in war, and under enemy air activity, control would be more difficult and administration and welfare of the drivers would become most difficult. Nearly all bridging equipment now, and in the future, will be package or parcel loaded, each package weighing approximately a ton or a ton and a half. This factor, provided an adequate number of cranes are available in the Engineer dumps, greatly speeds up loading. It will also speed up unloading at the bridge sites which should in turn speed up the turn-round of vehicles. It is here that the

R.A.S.C. officer can influence engineers by constantly reminding those concerned in the loading of bridging equipment of the importance of adhering to standard loads, and of not attempting to split the R.A.S.C. organization.

Communications

Communications on the R.A.S.C. net are far from adequate. There should be a wireless link between C.R.A.S.C., the bridge point and each of his companies. The C.R.A.S.C. should ask the C.E. for sets to cover these requirements.

Over Insurance

There is a tendency for an excess of bridging transport to be held forward. Although the engineers may wish to have the transport up or near the bridge points, this is contrary to present-day teaching. In particular, any tendency towards over insurance must be guarded against.

Bridge Points

If a Bridge Company Headquarters is detailed to run a bridge point it is not necessary to use the whole of the Company Headquarters. One captain, one subaltern, the R.E. Troop Officer, the attached R.M.P. and a few N.C.Os. are quite adequate. The Company Headquarters should never be divorced from its primary rôle of controlling and administering its own platoons. On the other hand when sections of transport are held forward by field squadrons, these squadrons must accept responsibility for their administration. It is desirable that during periods of intensive bridging activity bridge companies are on composite rations so that they can easily be divided.

Movement by Day

The question of movement by day must be considered. It is not always possible to bring the bridge equipment up to the sites or marshalling harbour areas during darkness, and then to wait a further twenty-four hours before commencing to build. The movement of this bulky transport presents a big problem and risks will have to be taken in filtering this transport forward during daylight. However, on exercises, risks are taken which would not be permissible in war. Full use should always be made, when the necessity arises, of the Royal Military Police and the use of their "Priority" signs for movement on the roads. Guides from squadrons should always be sent to the bridge point to collect their loaded vehicles and lead them forward to their respective squadrons.

The Necessity for a High Standard of Training of the R.A.S.C. Driver

Once bridging loads are held forward in the harbour areas it may become necessary to phase individual vehicles forward to the actual bridging sites. The latter part of this journey may have to be made over difficult terrain unescorted. It is imperative that bridging loads arrive at the bridging site in the order determined by the engineers.

The adverse effect on a bridging operation of one vehicle failing to reach the bridging site cannot be over-emphasized. A very high standard of training in map reading and cross country driving is therefore required of the R.A.S.C. driver to ensure that he does arrive at the site at exactly the correct time. Even though the route from the marshalling harbour area should be marked by the engineers this is not always possible, and it is left to the individual driver to get to the site by himself.

Non-Standard Loads

There is always difficulty over the use of non-standard loads and it is suggested that the engineer officer at a bridge point should be empowered to reject any non-standard loads and request replacements.

Positioning of C.R.A.S.C. Bridge Column

The positioning of the C.R.A.S.C. of the bridge column is most important. It is not considered wise to have him too far forward. He must be close to the C.E. Army and in good communication with him. He must also exercise control over his companies. This is most effectively done when he is close to their refilling points, e.g. the advanced engineer stores regiment or bridging dump elsewhere in the army area. Here he can have his companies dispersed and yet fully under his operational control. He can control their forward movement and refilling as directed by the C.E., and also look after their welfare. An officer representative must be detailed for liaison with C.C.R.E. at Corps, but under no circumstances should this be C.R.A.S.C. himself.

Conclusions

During the advance, the move forward of bridging stores may well be far more urgent than the replenishment of other commodities. Bridging transport has of necessity to be deployed in set loads and brought forward to the bridging site in a pre-determined order. The final responsibility for ensuring that the correct load is phased in at the right time often rests with the individual R.A.S.C. driver. The driver employed in a bridge company requires to be more highly trained than the average, since he is required to identify and drive a wide variety of awkward loads and be able to navigate unaided to the bridge site. The feeding and administration of the individual driver is more difficult than in a normal column.

Finally, the need for good relations and mutual confidence between the Royal Engineers and the Royal Army Service Corps at all levels cannot be overstressed. It is on this factor that:—

(*a*) any tendency to over insure may be eradicated.

(*b*) the R.A.S.C. officer can be a restraining influence on non-standard loading and on any attempt at breaking down the R.A.S.C. organization.

(*c*) the ultimate success of a bridging operation may well depend.

RADAR CONTROLLED AIR SURVEY PHOTOGRAPHIC OPERATIONS IN AFRICA, 1946-52

By Major S. Hellings, R.E.

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Formation of the Directorate of Colonial Surveys

IN 1943, the Colonial Research Committee accepted a proposal submitted by the Colonial Survey and Geophysical Committee to the effect that a Central Colonial Survey Organization should be established to undertake geodetic surveys and topographical mapping, publish the work completed, hold the required equipment and maintain the necessary records. In order that such an organization, if approved, could commence to operate as soon as possible after the end of war, a detailed scheme was called for by the Colonial Research Committee.

The reasons for the setting up of such an organization were as follows:—

In the past, colonies financed surveys out of current revenue which resulted in topographical surveys following instead of preceding development.

Orderly development of land and mineral resources should be based on complete and accurate knowledge of topography. Such surveys are in effect the first stage of planning for development. If an air survey unit was used, the subsequent photography should be of very considerable value for the recognition of geological features quite apart from the maps produced from the photography.

Geodetic survey is essentially a matter which must be planned for a whole geographical region.

Topographical mapping by aerial survey could be undertaken far more rapidly and at more economical rates than by the Survey Department of individual colonies.

Surveyors could be transferred from work in one colony to another and so carry out their duties throughout the year, instead of only during seasons.

Drawing, printing and publishing could be done much more economically and efficiently by a central body than by many small units.

A Sub-Committee of the Colonial Survey and Geophysical Committee was appointed to prepare a scheme. A brief summary of its recommendations is as follows:—

The Central Organization should be established in London under a Director-General, who would be responsible to the Secretary of State for the Colonies. The geodetic and topographical surveys in the colonial territories and the subsequent computations as well as the compilation and publication of the resultant maps should be undertaken by a staff provided by the organization.

The immediate task of the organization should be to complete the whole of the geodetic and main framework and 50 per cent of the outstanding topographical work covering all the important areas. The geodetic work should be carried out by ordinary ground methods, while most of the topographical work should be undertaken by means of air survey photography provided by the Royal Air Force, or an air survey unit of the organization. The yearly target of photography should be such as to cover 80,000 square miles at 1/30,000 contact scale.

Maps should be produced at the following scales:—

1/125,000 covering the whole area surveyed.

1/50,000 covering the more developed areas and such areas as are specifically required. Where, however, the 1/62,500 scale had already been used for existing maps, this scale would continue to be used.

1/25,000 or larger scales for areas of special economic importance.

Prints of the air survey photography should be made available to local survey, geological, agricultural and forestry departments.

Colonial governments were asked to inform the Secretary of State of the areas to be photographed and mapped by this organization, giving the various areas in order of priority of urgency and stating the reasons for each priority. By this means the planning of the yearly programmes of the organization could be carried out in accordance with the wishes of all colonial governments. The order of priority of the work to be undertaken was to be decided by the Secretary of State with the assistance of his various advisers interested in the development of the areas concerned.

The Secretary of State for the Colonies approved the scheme for the formation of a Central Organization in August, 1945. It was decided that the R.A.F. should provide an air survey photographic unit and on the 11th March, 1946, the headquarters of the Directorate of Colonial Surveys was opened at Teddington, Middlesex.

The Air Survey Photographic Unit

As a result of the decision that the Royal Air Force should provide the air survey photographic unit, a flight was deployed in March, 1946, to Accra (Gold Coast) to commence photographic operations. The programme for that year was ambitious and included the whole of the Gambia and parts of Nigeria, Gold Coast and Sierra Leone, totalling an area of 145,000 square miles. Although this flight was later increased to six aircraft, unsuitable weather prevented the completion of the task, and in February, 1947, the aircraft returned to the United Kingdom to reorganize for deployment to East Africa. During April and May, 1947, a complete Squadron, 82 Squadron, Royal Air Force, moved to East Africa to be based at Royal Air Force Station, Eastleigh, Nairobi. Since then, this squadron has operated in turn over territories in East, West, Central and South Africa and parts of the Middle East. Its capacity for deployment and administration was perhaps most apparent when, for a period, separate detachments operated at the same time in the Middle East, Sierra Leone, Southern Rhodesia and Kenya, in each of which, with the exception of Kenya, radar controlled photographic tasks were undertaken. The distances of these detachments from the squadron base in Nairobi were respectively 2,500, 3,600 and 1,400 miles approximately.

Attached to the squadron is a Radar Air Survey Liaison Section, Royal Engineers. The function of this unit is to assist in all matters relating to the survey photography undertaken by 82 Squadron, Royal Air Force, for the Director of Military Survey, War Office, and to interpret the technical needs of the Director of Military Survey. By agreement between the War Office and the Colonial Office the section also performs a similar function on behalf of the Director of Colonial Surveys. The responsibilities of this unit are as follows:—

To examine all survey photography taken for the Director of Military Survey and the Director of Colonial Surveys and to accept or reject this photography in conformity with the technical standards laid down from time to time.

To plot the survey photography taken and to inform the Royal Air Force Squadron of the extent of the cover.

To maintain cover diagrams for all survey photography.

To calibrate and maintain records of all cameras used for survey sorties.

To advise the squadron on the flight lines necessary to meet survey requirements.

To compute flying programmes for radar control.

To co-ordinate radar beacon sites by trig survey or field astronomical methods.

To complete all radar control data which may be necessary subsequent to photography.

The Survey Aircraft and its Equipment

The survey aircraft has a range of 2,300 miles, which is increased to 2,900 miles if two overload tanks are fitted, although these are not normally fitted. For survey photography it has a ceiling of 23,000 ft., cruises at an average speed of 200 knots and is manned by a crew of four consisting of a pilot, a navigator a signaller and a flight engineer who also acts as a camera operator. The installation of radar equipment, by means of which ranges can be determined to ground radar beacons, provides a most useful navigational aid during photography. The use and advantages of this will be outlined later in this paper.

Most of the air survey cameras at present held by the squadron are American manufactured Fairchild K17, although these are being replaced by the British manufactured Williamson F49, a few of which are now in use. The ranges of adjustment of the aperture and shutter speed of the two cameras are as follows:—

K17 (f6.3–f22) (1/50–1/300). F49 (f6.3–f11) (1/50–1/200)

Both cameras have a 6-in. focal length lens and can be operated automatically or manually. The pilot has a Type 35 automatic control at his disposal by means of which, having set the appropriate interval between successive exposures, the camera can be automatically operated. Provision is made for manual operation by means of a button, which, when pressed, results in an immediate exposure. The camera is positioned in the nose of the aircraft in a mounting which permits lateral and fore and aft levelling and corrective drift setting. Another British manufactured camera, the Williamson F24, is installed towards the rear of the aircraft and is automatically triggered by, and operated simultaneously with the air survey camera, and photographs certain instruments in the aircraft. The data so provided can be used in the subsequent map making.

Brief Explanation of Radar Equipment used by the Squadron

The aircraft carry a radar transmitter and send a series of short pulses of radiation which, for the purpose of this description, we may call simply pulses. The pulse is received by a radar beacon on the ground and after a short pause, the duration of which can be determined, the beacon sends an answering pulse which is received by the aircraft. Because the pulses are travelling at a sensibly constant known speed (approximately 186,000 miles per second), the interval of time between the aircraft transmitting a pulse and receiving the answering pulse from the beacon, is a measure of the distance between the aircraft and the beacon. To determine this distance, arrangements are made to measure this interval of time very accurately (to within a fraction of a micro-second).

This is done in the following way: A spot of light is made to move very rapidly, to and fro, across the face of a cathode ray tube in the aircraft. This movement is so rapid that the persistence of the human eye creates the illusion of a continuous straight line of light. At the instants that the aircraft transmits its pulse and receives the return pulse from the beacon, the spot of light is deflected upwards. This results in the portrayal of the positions of the two pulses relative to the same straight line, the distance between the same being proportional to the distance between the aircraft and the beacon. Gee Unit graduation marks are added to this line by electronic means to form an easy means of measurement (termed a time base) from which the distance between the aircraft and beacon can be determined to approximately 0.002 Gee Units (approx. 20 metres).

It follows that if the crew want to fly at a certain distance from the beacon they can do so by identifying the graduation mark on the time base corresponding to that distance and fly the aircraft to a position where the return pulse coincides with that particular graduation mark. For convenience and accuracy the appropriate parts of the time base are enlarged and portrayed in a form similar to, but by no means the same as a vernier. The transmitted and return pulses appear respectively above and below the time base and a pre-selected range is reached when the two pulses become aligned. Two sets of time bases are provided in order that the ranges to two beacons can be portrayed when required. Other cathode-ray tubes, giving a similar picture to that seen by the navigator are fitted in an assembly called an Automatic Observer. These, together with duplicate flying instruments, are photographed by a separate camera every time a photograph is taken of the ground and a permanent record is thus made of the range from the beacon, and of the flying conditions in which the survey photograph was taken.

From the foregoing it can be seen that an aircraft can be maintained in flight along a track which, ignoring deviations due to errors on the part of the pilot and/or navigator, is at a constant range from the radar beacon. With trained crews such deviations from track are usually very small and at the most are 400 metres. Subsequent tracks can be selected and flown such that the whole area to be photographed can be covered with strips of photography of which adjacent strips overlap each other by an amount depending on the spacing of the selected ranges. Where adequate ground control exists or can be established, this is the method by which 82 Squadron photographs an area. Where little or no ground control exists it may be provided by the use of two ground radar beacons. These must, of course, be subsequently co-ordinated in relation to each other and to some ground control. In this case the aircraft, while tracking on one beacon, interrogates the second beacon. If the ranges to both beacons are determined, the aircraft (or the plumb point of any photograph taken by the aircraft) can be co-ordinated in relation to the beacons and the co-ordinate system to which they are related.

The advantages of radar as a navigational aid for air survey photography can be summarized as follows:—

Adjacent parallel strips of photography with any required lateral overlap can be obtained with comparative ease.

The photography of gaps left in previous radar controlled photography can be obtained with similar ease.

Flying time and photographic materials expended on photography are kept to a minimum, providing the equipment is serviceable.

The skill required by pilots and the consequent training is less than that required for photography obtained without this type of navigational aid.

When two beacons are used, the aircraft (or the plumb point of any photograph taken by the aircraft) can be fixed in relation to the two beacons providing the ranges from each intersect suitably.

Determination of Ranges and Position of Aircraft

The data from which the range of the aircraft is determined is obtained by the following means. A housing mounted near the rear of the aircraft contains a duplicate set of the following instruments:—

Air temperature indicator.
Pitch and drift indicator (relating to the camera).
Air speed indicator.
Pitch and roll indicator (relating to the aircraft).
Altimeter.
Watch.
Cathode ray tube.
Veeder counter.

Of these, the pitch and drift and pitch and roll indicators can be ignored. The former is no longer used, as it was designed for a different type of camera mounting to that at present used by the squadron, while the pitch and roll indicator is of little use as it is not sufficiently accurate and relates solely to the attitude of the aircraft as opposed to that of the camera. An F24 camera, less shutter, is mounted so that it can photograph these instruments and the whole assembly is enclosed in a light-tight housing known as an Automatic Observer (A.O.).

The A.O. is electrically connected to the air survey camera which makes vertical exposures of the terrain. Each time such an exposure is made the A.O. is simultaneously triggered by electrical means, so that all the instruments are illuminated and the time base which portrays the radar range appears on the C.R.T. These sources of light, appearing for approximately 1/5 sec., are recorded by the film in the F24 magazine, which is then automatically wound on to await a repetition of the same operations when triggered again by the air survey camera. One should remember here that the C.R.T. display in the A.O. is controlled by the navigator who has a similar but not identical C.R.T. display at his disposal.

The films from the air survey and A.O. cameras are subsequently processed and each A.O. negative is correlated with the air survey negative which was exposed at the same instant. The following can then be read from the A.O. negative:—

Indicated height of aircraft at exposure.
Indicated slant range of the aircraft from the beacon at exposure.
Indicated air temperature.

It should be noted that the determination of altitude does not simply consist of reading the altimeter from the negative. A lengthy computation is involved in which the indicated altimeter reading is adjusted to allow, as far as possible, for a number of variable factors.

The slant range read from the C.R.T. must also be corrected to allow for the beacon delay that exists between the receipt and transmission of the pulse. By determining the difference in height between the aircraft and the radar beacon, which has been heighted and co-ordinated by field surveyors on the ground, the slant range from the aircraft to the beacon is corrected to horizontal. This can be used to plot the track of the plumb points of the photographs. Similarly, if the horizontal ranges from the aircraft to two surveyed radar beacons are determined, the position of the plumb point of each photograph can be plotted on the same co-ordinate system as that on which the radar beacons are surveyed. By analysing the tilt of the photography the position of the plumb point of each photograph can be found in relation to the position of the principal point. The position of the principal point is always known in relation to the point at which the lines joining opposite collimating marks intersect.

The Specification and Classification of Photography

All air survey photography produced by the Squadron is classified X, Y or Z. Any negative that does not fall into one of these classifications is totally rejected and is destroyed. A brief description of the three classifications is as follows:—

Class X. Negatives of high quality which permits their use for normal survey methods without undue difficulties or delays.

Class Y. Below X classification but within the limits set for Y classification in the detailed specification.

Class Z. Below Y classification but which may be of some use.

In order to show why a Class Y or Z negative has failed to reach a higher standard, the classification letter is followed by the numbers 1, 2 and/or 3, which relate to a lack of standard in one or more of the following:—

1. Cloud or cloud shadow.
2. Perspective requirements.
3. Photographic quality.

The detailed specification and system of classification of air survey photography is shown in the table opposite.

The Means by which the Specification of Air Survey Photography is Obtained

If one assumes that the appropriate photographic materials and equipment are available and weather conditions are suitable for air photography, the remaining specifications to be considered are as follows:—

(*a*) *Preservation of Specified Scale.* The contact scale of photography is determined by the relationship between the focal length of the camera and the height at which the exposure is made above the

	Class X	Class Y	Class Z
1. Cloud Cover.	(*a*) No cloud, or cloud shadow that obscures detail on any part of the stereo-overlap. (*b*) Tilt not exceeding 2°. (*c*) Fore and aft overlap 55% to 65%.	(*a*) Up to 10% of cloud or cloud shadow on any one negative provided that the detail obscured is visible on the adjacent negative. (*b*) Tilt generally less than 5°. (*c*) Fore and aft overlap more than 65% or less than 55% provided that the area common to 3 photos contains at both ends suitable pass points of clear detail identifiable on all 3 photographs.	
2. Perspective Requirements.	(*d*) Lateral overlap within the requirements laid down for the job. (*e*) Crab less than 5°. (*f*) Relevant collimating marks must be distinct.	(*d*) Lateral overlap such as to contain suitable tie-points intersectable on, and common to, both strips at intervals not greater than 1 in every 4 consecutive exposures and such that there are no gaps in the stereo-cover. (*e*) Crab such as will not vitiate condition (*d*) above on either side of the strip. Generally 15° is the limit. (*f*) Relevant collimating marks must be distinct.	Negatives falling in any way below Class Y but which may be of some use, particularly if no "Y" or "X" class of the same area is obtained.
3. Photographic Quality.	(*g*) Definition good: (i) Contrast such that prints made by normal method on standard Royal Air Force papers will show ample detail throughout the full range of tones. (ii) Free from all blemishes such as fogging, uneven processing and mechanical damage.	(*g*) Photos will be of varying quality but minimum requirements are such that: (i) Identification of detail from one photo to another can be made with certainty to 0.1 mm. (ii) Stereo fusion is possible throughout the overlap. (iii) Detail normally required for surveying at the given scale can be interpreted with 90% certainty.	

terrain photographed. If f = focal length of the camera, and H = height of aircraft above the terrain, then f/H = scale of photography. With a 6-in. lens camera the denominator of the representative fraction of the scale equals twice the height of the aircraft in feet above the terrain to be photographed. Owing to the variation in height of the terrain, some departures from the specified scale must be tolerated, but should be kept to a minimum. This may entail photographing parts of the terrain from different flying heights. The usual scale of photography required by the Directorate of Colonial Surveys for topographical mapping is 1/30,000 which means the aircraft flies at 15,000 ft. above the average height of the terrain. Assuming $\pm$ 1/2,000 to be the maximum tolerable departures in scale, it is clear that the lowest flying height above the terrain is 14,000 ft. In view of the fact that the ceiling of the Lancaster aircraft in use by the squadron is 23,000 ft., terrain higher than 9,000 ft. A.M.S.L. presents a problem if the specification of approximately 1/30,000 scale photography is still to be met. Where such terrain is extensive, the practice has been to engage aircraft with a higher ceiling using 6-in. lens cameras. Examples of this are Mount Kenya and part of the Aberdares in Kenya, and the Ruwenzori range and Mount Elgon in Uganda.

(*b*) *Elimination of Tilt.* After the aircraft has reached operational height, the camera operator requests the pilot to fly a straight and level course, and with the aircraft in this attitude the camera is levelled. During photography, the camera operator continually checks that the camera remains level during exposures. To the same end, the pilot is warned of the approach of each automatic exposure by means of a red light which appears for 4 sec. before the exposure, after which a green light appears which indicates that the exposure and film winding mechanism are in operation. The red light assists him to maintain a level and correct course at the instant of exposure and, should he fail to do so, he can expose the camera at any instant by means of a push button. Such exposures are termed "snaps" and are intended to be made after the aircraft attitude has been corrected. They have their limitations, however, as lack of fore and aft overlap may result if the pilot is too long in correcting the aircraft. "Snap" exposures are also made to facilitate correlation of the air survey and A.O. negatives.

(*c*) *Maintenance of the specified fore and aft overlap.* Fore and aft overlap depends on the scale of photography and the ground speed of the aircraft. The R.A.S.L.S., R.E., prepare a table for the aircrew which lists the appropriate time intervals between successive exposures that should be used for varying aircraft ground speeds in order to produce 60 per cent fore and aft overlap in the subsequent photography. To allow for rise and fall in the terrain photographed, the table lists this data for varying photographic scales or flying heights above the terrain. By this means the appropriate time interval for any required air speed and for any height above the terrain can be selected and set on the camera control.

The formula used to compute this table is $I = \frac{0{\cdot}6DW(1 - P)}{K}$

Where I = Interval between successive exposures in seconds.
D = Denominator of the photographic scale's representative fraction.
W = Width of Camera format in the fore and aft direction in feet.
P = Percentage of fore and aft overlap required.
K = Ground speed of aircraft in knots.

(*d*) *Maintenance of the special lateral overlap.* Lateral overlap depends on the scale of photography and the spacing of the flight lines. The amount specified is 25 per cent ± 5 per cent. Greater amounts are tolerated but they are inconvenient and uneconomical. If flight lines are spaced at 0·5 Gee units (5,000 metres) which is convenient to all concerned, a lateral overlap of 27 per cent will result between adjacent strips of photography flown at 15,000 ft. above the terrain with a 6-in. lens camera. Another table prepared by R.A.S.L.S., R.E., lists the percentage of lateral overlap that results for varying photographic scales and varying spacings of flight lines.

(*e*) *Elimination of crab.* When the fore and aft direction of photography differs unduly from the course of the aircraft, the photography is described as "crabbed". Crab results purely from errors on the part of aircrew, except where the flight line on which the aircraft is tracked from a radar beacon has such a small radius that the direction of flight changes excessively between successive exposures. In such circumstances excessive tilt will also probably occur. To obviate this, the range of flight lines is kept to a minimum of 6·0 Gee units, which means that the area within this radius of each beacon site must be photographed by visual means or by tracking on another beacon. The aircrew faults which may result in crabbed photography are:—

Failure to maintain the fore and aft direction of the camera aligned with the true course of the aircraft by incorrect drift setting.

Allowing the aircraft to move off course and then returning to course too rapidly.

Erratic flying.

Operations Involved in the Photography of an Area

(*a*) *Deployment of personnel and equipment.* The areas to be photographed and the specifications of photography are laid down by the Directorate of Colonial Surveys. A suitable base from which the aircraft are to operate is selected as near the area as possible and a reconnaissance is made for radar beacon sites which should meet the following requirements:—

To be within approximately ten miles of an airstrip which can be used by the aircraft that transport the radar beacon equipment and stores.

To be higher than the surrounding terrain, preferably removed from any other hills in the vicinity.

To be sited so that the ranges extend over as much of the area as possible and provide flight lines from which photographic cover can be obtained most economically.

To be within fifteen miles of accommodation suitable for a crew of one officer and six men.

To be, as far as possible, accessible by wheeled motor transport.

The beacon crews and equipment are then deployed by transport aircraft. Each beacon site is later heighted and co-ordinated by a field survey party of the R.A.S.L.S., R.E., by the most suitable means. Preferably, this is done by connexion to the nearest reliable trigonometrical control. Where such control is not available, field astronomical methods are used to obtain the approximate geographical co-ordinates of the site, while an approximate height is obtained by means of aneroid barometers. Delay in the survey of the beacon sites does not delay the photographic operations for which only an approximate fixation (e.g., map spot) is necessary. It should, however, be completed before the Directorate of Colonial Surveys commences mapping if full use is to be made of the radar control data.

The flying detachment, consisting usually of two Lancaster aircraft, eight aircrew and twenty ground crew, including signallers, radar mechanics, fitters, riggers, photographers, safety equipment personnel, drivers and cooks, with stores and equipment required for the servicing of aircraft, is then deployed to the selected airfield. A representative of the R.A.S.L.S., R.E., accompanies each flying detachment for the purposes of briefing and debriefing. This deployment necessitates the use of three fully-loaded Dakota transport aircraft, assuming no servicing stores are available at the airfield for the squadron's use.

(*b*) *Briefing*. This is considerably simplified by the provision of certain flight data for each survey aircraft that may be engaged over parts of the same area at any one time. R.A.S.L.S., R.E., prepare flight diagrams at 1/1,000,000 scale covering the area to be photographed over which arcs of circles, concentric to the radar beacon site, representing flight lines, are appropriately spaced, such that the required lateral overlap will result between adjacent strips of photography. The radius of each arc, expressed in terms of Gee units, is clearly portrayed on the diagram. Lines of true bearing radiating from the beacon are spaced at every 5 deg. from true north, at the end of each of which its true bearing value and the aircraft heading value is shown. The aircraft heading is the direction of flight relative to true north of an aircraft flying tangential to any one plotted flight line. When the aircraft crosses a line of true bearing its heading equals the true bearing value of the line plus or minus 90 deg. The heights at which aircraft should fly to obtain 1/30,000 scale photography with a 6-in. lens camera are shown within the boundaries of the areas to which they refer. A table is attached from which the time interval between successive camera exposures, appropriate to the ground speed of the aircraft, can be selected which will result in the required fore and aft overlap throughout the photography.

The flight diagrams are prepared on maps and plain paper, each of which are at 1/1,000,000 scale, the latter being more suitable for recording the progress of photography, the extent of which is defined by range and bearings from the radar beacon. Although one obvious advantage of such flight diagrams is the ease by which the extent of required photographic cover can be defined, the extent of the claimed photography may not be accurate in so far as the starting and finishing bearings are concerned. Assuming no other sources of inaccuracy are involved the starting and finishing bearings may both be in error up to $\pm$ 10 deg. approximately. This will readily be appreciated when one remembers that, if such a bearing is to be accurate, the aircraft heading must be exactly tangential to, or parallel to a tangent of, the flight line. Any deviation from this in the aircraft's heading results in an equal error in the bearing.

(*c*) *Aircrew Drill.* After course has been set for the area of photography, the radar beacon is informed by W/T of the proposed photographic runs. From the indicated altimeter height the navigator computes the true height of the aircraft, which is then adjusted accordingly until the required height is reached.

On arrival near the first run the navigator determines a three drift wind and informs the engineer of the compensating drift setting that should be set on the camera mounting, such that the fore and aft direction of the camera will coincide with the true course of the aircraft. After computing the ground speed of the aircraft, he selects the appropriate time interval between successive camera exposures, which is then set on the automatic control of the camera by the pilot. With the aircraft flying straight and level, the engineer levels the camera and continues to check this throughout the photography.

Meanwhile the navigator has pre-set the required tracking range (termed the beam) on the radar equipment and has selected the aircraft headings at which the photographic run is to start and finish. By watching the two radar pulses portrayed on the cathode ray tube he directs the pilot to fly the aircraft at this range. The beam is approached at right angles and when approximately 0·3 Gee units (3,000 metres) distant, the aircraft is turned towards the beam in a rate 1 turn. When the transmitted and return pulses are aligned, the aircraft is then on the beam.

With the aircraft on the beam, the pilot commences the automatic operation of the camera as the starting aircraft heading is reached. The navigator continues to "talk the pilot round the beam" during photography, care being taken by both that any deviations from the beam are not corrected too rapidly as otherwise crabbed photography will result. Near the beginning, middle and end of each run, the pilot should make "snap" exposures, which are readily identified in both the subsequent air survey and A.O. negatives and facilitate the correlation of the two. From a veeder counter on the air survey camera, the engineer decides when magazines should be changed and notifies the remainder of the crew. The pilot then suspends the automatic operation of the camera, orbits the aircraft during which the engineer and signaller change the magazines on the air survey and A.O. cameras. When the aircraft is again on the beam, the automatic operation of the camera is recommenced by the pilot so that the last few exposures of one magazine are duplicated by the first few exposures of the following magazine, thereby ensuring continuous stereoscopic cover throughout the run.

When the finishing aircraft heading is reached, the navigator informs the remainder of the crew. The engineer then covers or partly covers the lens to provide an exposure by which the end of the run is readily identified when the subsequent photography is plotted, after which the pilot suspends the automatic operation of the camera. The aircraft is then turned into the next adjacent run and, if necessary, the drift setting and time interval between the exposures are adjusted accordingly, after which the same drill is repeated.

The signaller has to maintain a routine W/T contact with base and the radar beacon during the sortie and as his transmissions tend to interfere with the radar reception he should confine such W/T contacts to periods when photography is not in progress. With the exception of the pilot, each aircrew member maintains a log for each photographic run which, after landing, is compiled into a Flight Block Report. This report then accompanies the film during all subsequent stages.

(*d*) *Debriefing*. The representative of R.A.S.L.S., R.E., meets the aircraft on return from each survey sortie and compiles the forms that comprise the Flight Block Report, having checked that they are completed. He notes any points of interest, difficulties, etc., that the aircrew report and completes a record in which are entered all relevant details for each survey sortie. The extent of claimed photography is then signalled to base in terms of range and starting and finishing bearings from the radar beacon, after which it is entered on all copies of the flight diagram to which it relates, held by both the flying detachment and at base. Transparencies are attached to the flight diagrams for this purpose.

(*e*) *Photographic processing*. After the exposed film has been removed from the camera magazines and placed in light-tight tins, they are returned to base as soon as possible by schedule aircraft. The air survey film is developed, using a continuous processing machine, after which each air survey negative is numbered, and the whole roll of negatives is identified by a titling strip on which is shown the sortie number, date, height, territory and other relevant data. By means of multiprinter equipment, prints are made from the air survey negatives, on each of which appears an image of the titling strip and the appropriate number of the negative. The A.O. film is processed only, prints not being required as all the necessary data can be read from each A.O. negative if it is held over a negative viewing bench. The sortie number is entered on the end of the roll of A.O. negatives, but the numbering of each negative is not undertaken until the air survey and A.O. negatives have been correlated. The output of the photographic processing equipment can be seen from the following figures:—

Task	*Duration*
Developing 200 air survey negatives	1 hr. 30 min.
Printing 200 air survey negatives	30 min.
Developing 200 A.O. negatives	1 hr. 20 min.

(*f*) *Classification and plotting of photography.* After the air survey negatives and prints have been received by R.A.S.L.S., R.E., from the photographic section, a preliminary classification and general assessment of the quality of the negatives is made by inspecting them over a negative viewing bench. At this stage only the requirements concerning cloud, cloud shadow and photographic quality are considered. The prints are then laid down in the order in which they were flown, as indicated in the Flight Block Report and flight diagram, during which the fore and aft and lateral overlap is checked by examination of the ground detail common to each pair of successive and adjacent photographs. The other perspective requirements are then checked and the photography is allocated its final classification. Changes in classification are denoted by the appropriate negative numbers and a Sortie Classification Sheet is then compiled, on which is shown the classification of every air survey sortie negative together with other relevant details relating to the sortie.

The photography is then plotted on a 1/500,000 scale map or diagram, on which radar ranges and lines of true bearing from the radar beacon site have been plotted. Different symbols are used to denote the different classes of photography. From the plotting map or diagram the extent of each class of photography is determined and is then signalled to the flying detachment in the same terms as those used for the original claim. Where the claim is found to be in error, the expressions "add to claim" or "no photographs" are used in the classification signal. The flying detachment and base flight diagrams are then appropriately amended and all concerned are informed of the progress to date.

A Sortie Trace is then compiled for each individual sortie, consisting of tracing linen on which is shown the extent of each class of photographic cover of the sortie in question. Graticule or grid lines are entered in order that it can be related to the appropriate map, if one exists, and a copy of the Sortie Classification Sheet is attached.

The extent of the photographic cover of each sortie is then transferred progressively to a composite diagram termed a Master Cover Trace. This diagram consists of three separate traces on which is shown the extent of X, Y and Z class photography respectively.

The air survey and A.O. negatives are then correlated and the latter are stamped with the same numbers as the air survey negatives to which they refer. If serviceable watches are fitted in both the air survey camera and A.O., and clear images of each appear on the respective negatives, the correlation is a simple matter. This, however, is the exception rather than the rule and usually correlation is only achieved by reference to "snap" exposure. Such exposures are readily identified in the air survey negatives by the change in fore and aft overlap, while the A.O. "snap" exposure is identified by the change in the time interval as shown by the watch. Although this method is sound it is rather lengthy.

When required R.A.S.L.S., R.E., make the following recordings from each A.O. negative of the sorties:—

Radar Range; Air Speed; Altitude and Air Temperature.

Copies of these and the following photographic records relating to each air survey sortie are then dispatched as soon as possible to the Directorate of Colonial Surveys:—

Flight Block Report.
Air Survey Negatives.
A.O. Negatives.
Sortie Trace.
Sortie Classification Sheet.
A.O. Negative Readings.

On cessation of photography over the area in question, the Master Cover Traces are then dispatched in the same way.

(*g*) *Camera Calibration.* The air survey camera must be of such precision as to produce suitable negatives from which maps can be made which meet a required standard of accuracy. Calibration data is provided for each air survey camera by the makers and to ensure the camera still meets the required specification it should be regularly checked. The check consists of a field calibration, the resultant data of which is compared against the maker's original data. With the present number of cameras in use by the squadron, such checks are made on each camera at three monthly intervals and are carried out as follows. A calibration site is selected from which exposures can be made to record the images of a number of well-defined targets, each approximately at the same height as the camera. Normally two exposures are made with each magazine of each camera, both with the optical axis horizontal. For the first exposure one collimating axis is also horizontal and for the second exposure this collimating axis is vertical. A reseau is superimposed on the negatives before processing, by means of which corrections for film distortion can be made. From a combination of distances between the targets, as accurately measured on the negative and data obtained by theodolite observations to the targets measured at the calibration site, the following calibration data can be compared with that of the makers:—

Principal distance or plate perpendicular, which is defined as the perpendicular distance joining the internal perspective centre and the plane of the negative.

Position of the Principal Point in relation to the collimating marks, which is defined as the point where the principal distance or plate perpendicular meets the plane of the negative.

Separation of the negative images of the collimating marks.

Where the comparison shows an excessive discrepancy, the camera is returned to the U.K. for servicing and laboratory calibration.

Original Task, Progress Made and Problems Encountered

The area in square miles of the entire photographic task in Africa, assuming all areas unmapped or in need of revision were to be photographed, can be seen from the following:—

Territory	*Total area*	*Areas mapped topographically*	*Areas unmapped or in need of revision*
East and Central African Territories			
Uganda	80,360	62,500	40,860
Kenya	219,730	73,530	189,200
Tanganyika	360,000	20,800	339,200
N. Rhodesia	287,950	97,950	190,000
Nyasaland	48,000	—	48,000
Br. Somaliland	68,000	—	68,000
Zanzibar and Pemba	1,020	1,020	—
Seychelles	156	—	156
Mauritius	720	720	720
Total	1,065,936	256,520	876,136
West African Territories			
Nigeria	372,670	48,300	342,370
Gold Coast	91,840	54,560	37,280
Sierre Leone	27,920	27,920	27,920
Gambia	4,000	—	4,000
St. Helena and Ascension	50	50	—
Total	496,480	130,830	411,570

South African High Commission Territories			
Basutoland	11,716	11,716	11,716
Bechuanaland	275,000	—	275,000
Swaziland	6,704	—	6,704
Total	293,420	11,716	293,420
Total (All Territories)	1,855,836	399,066	1,581,126

Estimates of photographic materials and sorties required to undertake such a task can be made from the following:—

To cover an area with 1/30,000 scale air survey photography which meets the required specification described on page 157, it has been found that one photograph is required for approximately every 3 sq. miles of terrain. Although a 1/30,000 scale air survey photograph made with the K17/F49 camera, covers an area of $4\frac{1}{4}$ miles $\times$ $4\frac{1}{4}$ miles, allowance has been made for fore and aft and lateral overlap of 60 per cent and 27 per cent respectively and for various miscellaneous wastage factors.

On an average, a total of approximately 300 exposures is to be expected from each survey sortie. Although a number of varying factors prevents definition of the output of an average survey sortie, the figure above has been obtained from an analysis of the Squadron's progress over a considerable time and is suitable for planning purposes.

The extent to which the yearly target of 80,000 sq. miles was met, can be seen from the following summary of photographic cover obtained between 1st April and 31st March of each year:—

1946/47	34,200 sq. miles
1947/48	148,220 sq. miles
1948/49	195,830 sq. miles
1949/50	166,740 sq. miles
1950/51	255,760 sq. miles
1951/52	236,520 sq. miles

Totals as at 31st March, 1952: 1,037,270 sq. miles.

Comparison of the two sets of figures above does not, however, truthfully indicate the progress made towards completion of the photography of all the areas unmapped or in need of revision. This is due to the fact that some of the photography obtained covers territories not listed above, while the photography of other areas proved subsequently to be unsuitable, and some of these areas were later re-photographed. If, however, the total as at 31st March, 1952, is halved, the resultant figure gives an approximation of the number of camera exposures involved, and the quantity of air survey negatives that were processed, printed, classified and plotted. If the aircrew and ground crew man hours are also considered, together with the widespread areas of operations, a fair appreciation can be made of the effort maintained by the Squadron and the Royal Engineers Survey Section.

Of all the numerous difficulties encountered, many of which were beyond the squadron's control, unsuitable weather conditions proved to be the greatest, and all too frequently progress was severely restricted in consequence. Its consistency as a problem was not shared by its behaviour, evidence of which can be seen in the meteorological data of most of the African territories. The veil of modesty with which the weather tried to cloak a camera shy Africa, took forms including cloud, cloud shadow, ground mist, haze, harmattan, flood water and, on occasions, even snow. Other problems included the static marks resulting from film friction, smoke from bush fires and on one occasion the antics of a fair sized insect were recorded in its progress across the focal plane of a camera. It is perhaps as well that some of the problems were accompanied with humour, although most of these were experienced by the ground personnel.

In West Africa, considerable difficulty was found in retaining native porters at two radar beacon sites owing to the "presence" of a juju at each site. One was exorcised with the aid of two African Chiefs, one Wing Commander, one Squadron Leader, one Major and one D.C. and two bottles of gin. At the other site, a reluctant electrical generating set necessitated the frequent conveyance of spares up and down a very high hill. The local chief was convinced that this was due to another juju and his views were wholeheartedly supported by the native porters. Similar action was taken to dispose of the juju, although it would appear that the more economical methods (chickens, as opposed to gin being used in this case) were not so effective, because the generator's reluctance continued. This perhaps strengthens the case of the vegetarian.

At another detachment, a constant battle was waged against the local birds, which used to sit on the dispersal fences eagerly awaiting the returning Lancasters. Immediately the propellers had stopped turning, the birds flew into any opening in the engine cowlings or fuselage in search of nesting sites. A daily race resulted between the ground crews to seal these openings and the birds to start nesting, in which the ground crews did not always win. One morning, a nest, plus eggs, was found in the air intake of an aircraft that had landed at noon the previous day. The comfort of these aircraft was equally appreciated at another detachment by a swarm of bees which was discovered building a nest when the engine covers were removed.

It is regretted that time and space do not permit the inclusion here of more of the problems that were met. Although the solution of many provided both interest and amusement, those beyond the control of the Squadron were, to say the least, tiresome and frustrating. Had some of these problems not existed, particularly that of weather, the very creditable effort maintained by the Squadron and the Royal Engineers Survey Section would have resulted in an even better achievement both in quality and quantity.

"E. AND M. ODDMENTS"

THE BRUSH "AMPLIDEX" SYSTEM OF ALTERNATOR VOLTAGE CONTROL

By LIEUT.-COLONEL R. F. PRATT, R.E., A.M.I.E.E.

IN a previous article we have reviewed briefly modern trends in alternator voltage control. We will now examine in more detail an example of one of the so-called self-regulating alternators using a static electrical circuit in its voltage sensitive device. The system to be described is the "Amplidex", as used on the Dorman-Brush 62.5 kVA generating set shortly to appear in the service. Its action is of interest to Sappers, if only as an example of the static control circuit. The bulk of this article has been derived from a paper appearing in the *Technical Journal of the Brush Group* by Messrs. J. A. Raven, B.Sc., A.M.I.E.E., and A. L. West, B.Sc., A.M.I.E.E., to whom due acknowledgement is made. Certain amplifications have been added to clarify the description.

The block diagram is shown in Fig. 1. The voltage (or current) produced by the V.S.D. is applied to the sub-exciter and amplified up by the exciter system to give the controlled field for the alternator.

Now let us study the finer points of the V.S.D. This is one of the simpler circuits to understand and is given in Fig. 2 in simplified form to illustrate principles.

Generally speaking there are two branches, the "reference" branch and the "control" branch. Each is supplied from the alternator terminals by a transformer in the manner shown. The transformers are not identical. The one supplying the reference branch is run with its core well saturated at normal alternator voltage. That in the control branch is quite normal.

The action of the saturated transformer (T_1) is such that its output voltage is almost constant with variations of input voltage above the saturation limit. Its characteristic over the whole of the voltage range is given by curve (r) in Fig. 3 after rectification. As the input voltage builds up from zero, the output voltage rises almost linearly in accordance with the first part of the curve. When the input voltage has reached such a value that the core saturates at the peaks, the slope of the curve changes. As saturation increases, the characteristic follows the second part of curve (r) at a very much flatter slope.

Taking the characteristic as a whole, it will be seen that the saturated transformer acts as a "non-linear" resistor. There are other ways of doing it, but Brush have found this the cheapest for their particular circuit. The output is rectified and loaded across resistor R_2.

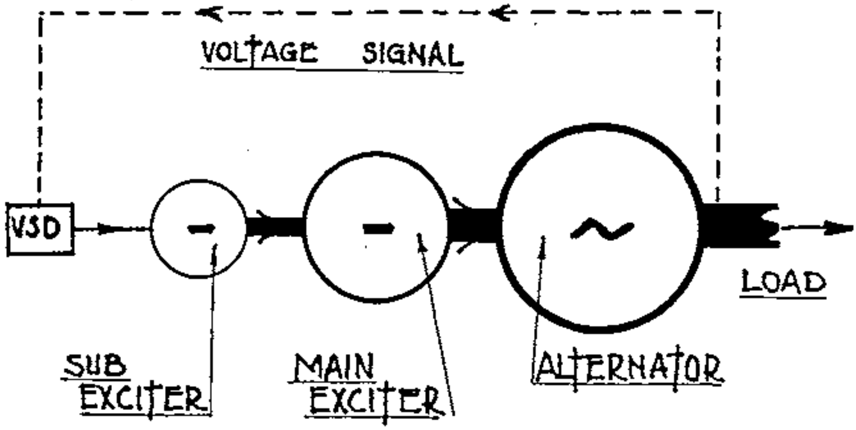

VOLTAGE SIGNAL
VSD
LOAD
SUB EXCITER
MAIN EXCITER
ALTERNATOR

FIG 1

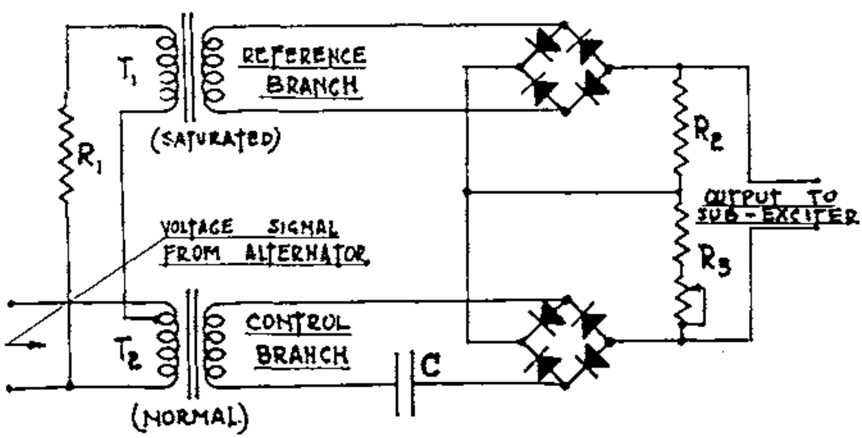
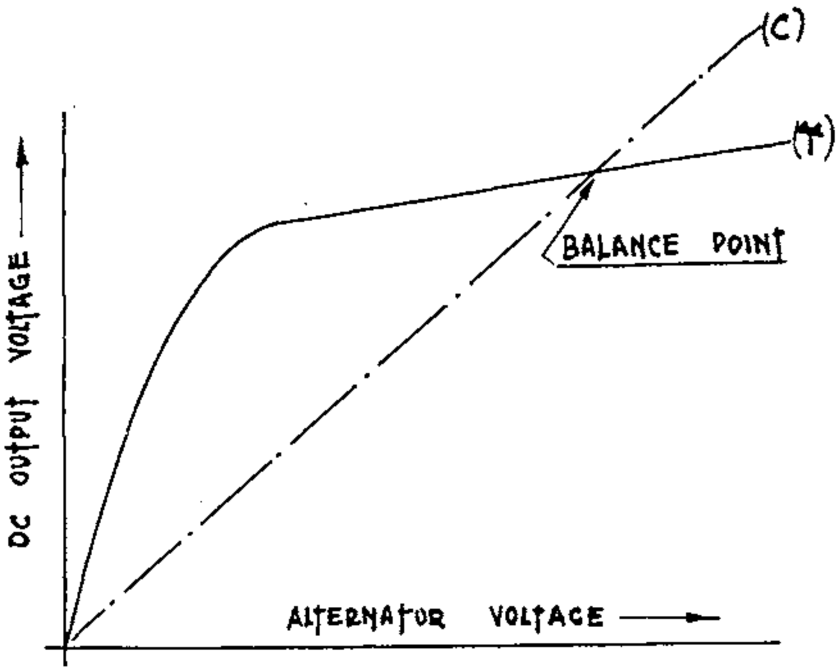

T1
REFERENCE BRANCH
(SATURATED)
R1
R2
OUTPUT TO SUB-EXCITER
R3
VOLTAGE SIGNAL FROM ALTERNATOR
T2
CONTROL BRANCH
C
(NORMAL)

FIG 2



—FIG 3—

The control branch transformer (T_2) is a normal one and has a linear characteristic with rise of A.C. volts. The secondary is connected through a condenser (C) to the rectifier and loaded across R_3, part of which is variable. All components in this branch are linear and the overall characteristic is curve (c) in Fig. 3—a straight line. Where the two curves intersect is the "balance point". We now have what might be called the "cross-over diagram", a feature of all these static circuits. The balance point is such that the voltages across R_2 and R_3 are equal and opposite and no output voltage is applied to the exciter. The balance point does not occur at the nominal output voltage of the alternator, but at some slightly higher value. The overall characteristic of the two branches is shown in Fig. 4. It is obtained by plotting the difference of the ordinates of Fig. 3 and converting the D.C. voltage output to milliamps for a given alternator; in this case a 50 kVA machine. The curve is not to scale, but is sufficient to show the form. It is desirable that the curve between A and B should be reasonably linear so that the circuit has the same sensitivity over the range which may be required to cope with switching transients. There must be a reasonable rise in output from 0 to 4 so that the alternator voltage builds up correctly when starting.

Under normal working conditions the output current to the sub-exciter is 1 mA, and as the load increases and the voltage falls the

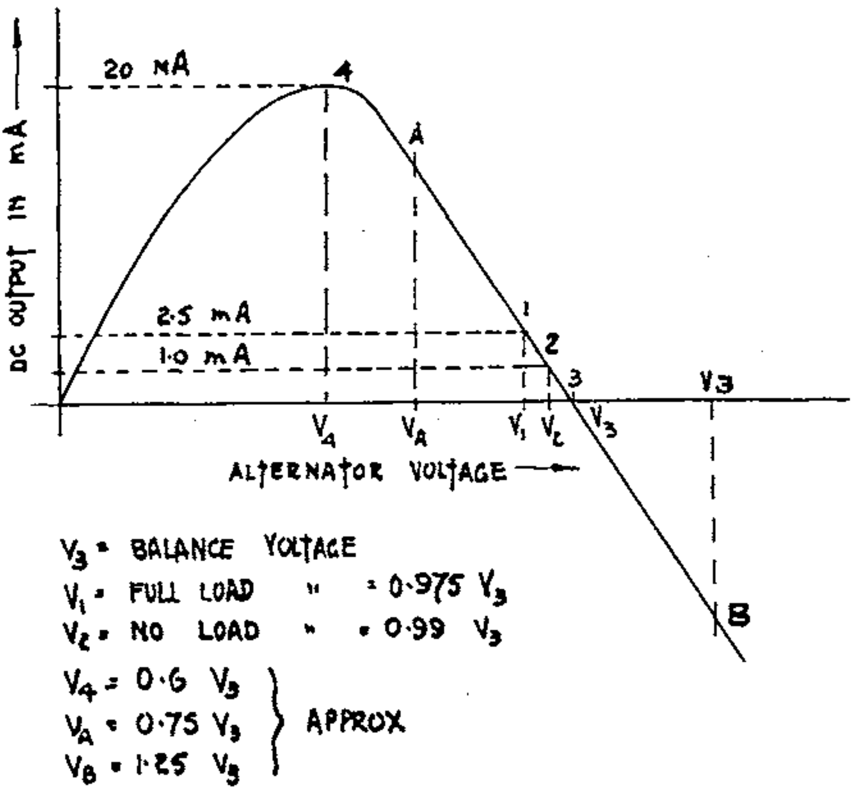

DC OUTPUT IN mA
20 mA
4
A
2.5 mA
1.0 mA
1
2
3
V3
B
V4
VA
V1
V2
V3
ALTERNATOR VOLTAGE
V3 = BALANCE VOLTAGE
V1 = FULL LOAD " = 0.975 V3
V2 = NO LOAD " = 0.99 V3
V4 = 0.6 V3
VA = 0.75 V3
VB = 1.25 V3
APPROX

FIG 4

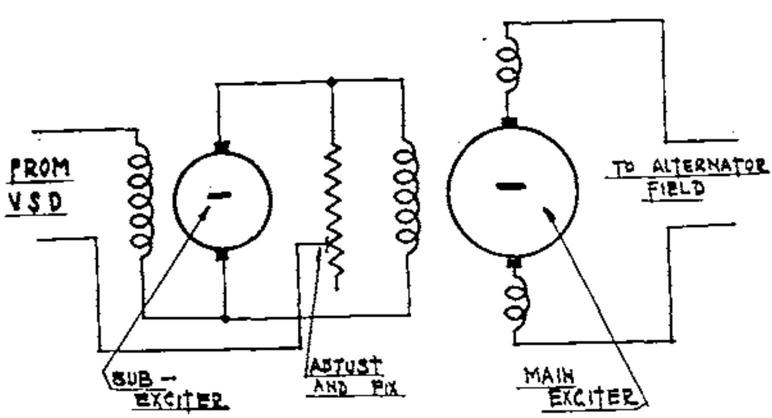

FROM VSD
TO ALTERNATOR FIELD
SUB - EXCITER
ADJUST AND FIX
MAIN EXCITER

FIG 5

output rises to 2.5 mA for this machine. This output is applied to the sub-exciter in a shunt field, as in Fig. 5. The current from the V.S.D. therefore normally adds to the shunt field from 1 to 2.5 mA. The amplification which takes place in the exciter system amounts to about 500,000 in power. This is made up by 50 times in voltage and 10,000 times in current. The V.S.D. can subtract from the shunt field under abnormal voltage surges and if there is a drastic drop in voltage it can produce a much heavier boost. These are, however, abnormal conditions.

The variable part of R_3 is used to alter the balance point. This then alters the no load voltage of the alternator manually to meet any given conditions. In the case of the military specification, this small rheostat has to give the $\pm$ 10 per cent manual setting variation over the nominal voltage. The variation permitted by this variable resistor R_3 is strictly limited, as the slope of curve (*c*) is affected by it. This in turn interferes with the sensitivity of the circuit by altering the slope of the part *A–B* of Fig. 4. It so happens that in this circuit the effect is not very pronounced, but in others it is, and special precautions have to be taken. It is therefore inadvisable to try to carry out the whole of the voltage adjustment in this manner with certain other static V.S.Ds.

So far all seems quite straightforward, but to give some insight into the designer's difficulties we must look more closely into the behaviour of the various components under certain conditions. The factors involved are frequency change, waveform and the effects of temperature.

Frequency

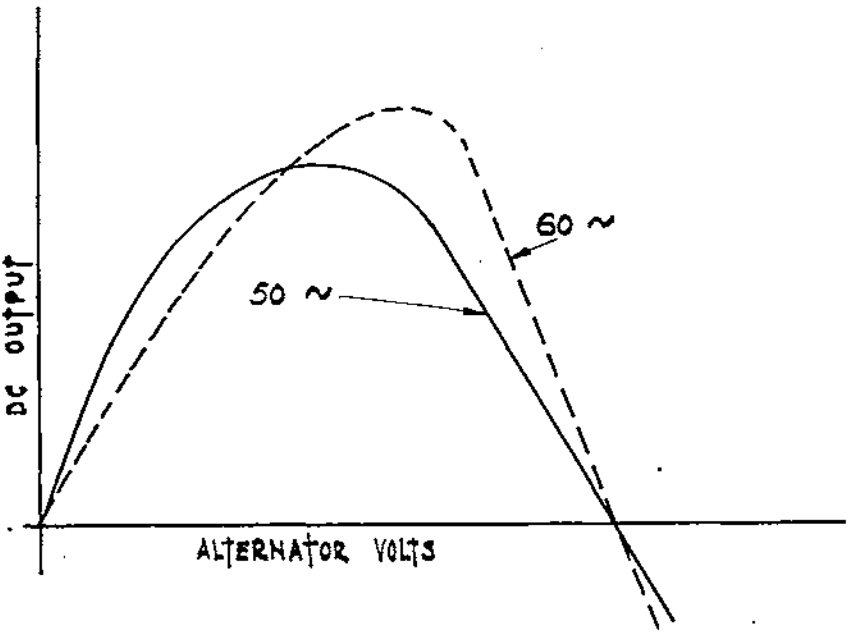
Unfortunately there must be small variations in frequency from no load to full load under the influence of the engine governor. There is a worse problem in the military dual voltage and frequency sets, which have to work equally well on 50 or 60 cycles. We can't have variations of frequency altering the voltage of the alternator and we do not want to do minor adjustments to the static circuit when we change over to 60 cycle working. In this case it is catered for as follows. Let us assume a 4 per cent increase in frequency due to full load being thrown off.

(*a*) What happens in the reference branch?

The supply transformer (T_1) is running with its core saturated and therefore its output voltage varies only as the fundamental frequency of the supply, the maximum flux remaining constant due to saturation. Its output therefore rises 4 per cent. This 4 per cent increase appears across R_2.

(*b*) What happens in the Control branch?

The output of its supply transformer (T_2) remains substantially constant as there is an increase in fundamental frequency and also in flux. Any increase of voltage due to frequency is cancelled out



—FIG 6—

by an increase in inductance. The impedance of the condenser (C) however drops 4 per cent with increase in frequency. The voltage across R_3 therefore also rises 4 per cent.

The balance point therefore remains unaltered and this is the reason for using a condenser as part of the linear resistor element in this branch. There is however a slight increase in sensitivity with increase in frequency. The sensitivity may be defined by the slope of the portion A–B of Fig. 4. The steeper the slope the more sensitive is the circuit. The shape of things is shown in Fig. 6 which gives a rough comparison of the characteristics at 50 and 60 cycles. Tests have shown that for the dual frequency sets, provided the sensitivity is high enough at the lower frequency, no modification is necessary to the V.S.D. circuit. A change from 50 to 60 cycles at no load causes the line voltage to vary by less than 1 per cent. On the service Dorman-Brush set there is, in fact, a changeover link for 50 and 60 cycle working. This improves the regulation at each frequency.

An interesting sideline to this effect of frequency is that if a V.S.D. of this nature is operated at a very much higher frequency the sensitivity can be made very high. This is what in fact has been done on a certain Admiralty generator driven by a gas turbine. It is thought that the static V.S.D. (in this case a B.T.H. "Magnestat") operates at 150 cycles.

Waveform Sensitivity

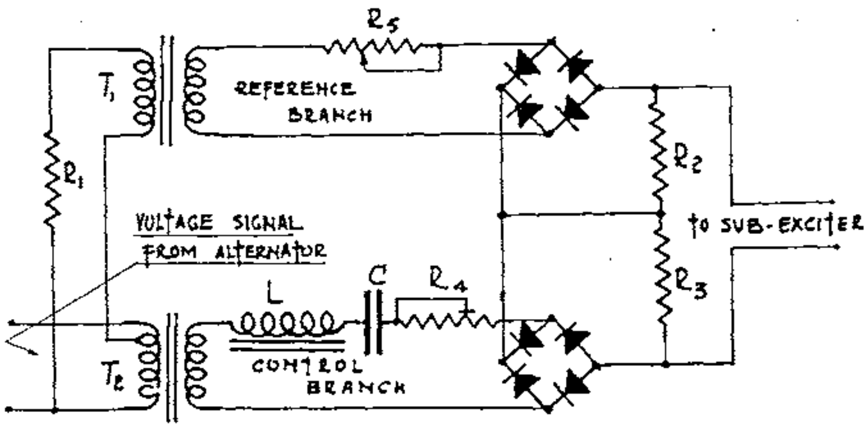
This one is a little awkward. Ideally, a V.S.D. should control the r.m.s. value of the voltage independent of the waveform. This is not possible to achieve exactly with this type of circuit, but a close approximation can be made by making the V.S.D. sensitive only to the fundamental frequency, in our case 50 or 60 cycles. Small harmonic contents have a negligible effect on the r.m.s. value. For instance, if the harmonic content is as much as 10 per cent the r.m.s. value is not altered by more than ½ per cent. The difficulty arises in the condenser in this circuit. The reactance of the condenser drops proportionately for successive orders of harmonics and therefore, if there are higher harmonics present, the control branch tends to over-estimate the voltage. The reference branch is dependent only on the fundamental frequency, as the average voltage across the saturated transformer is proportional to the change of flux per cycle divided by the period of the cycle. Neither of these quantities are affected by harmonics.

It might be argued that the alternator should be designed to give a pure sine wave, but in practice it is the load circuit which has the greatest effect on the waveform. It is particularly bad when grid controlled rectifiers or transductors are involved. The steep front to the wave when the rectifiers or transductors "fire", give rise to weird harmonics, however well the alternator is designed.

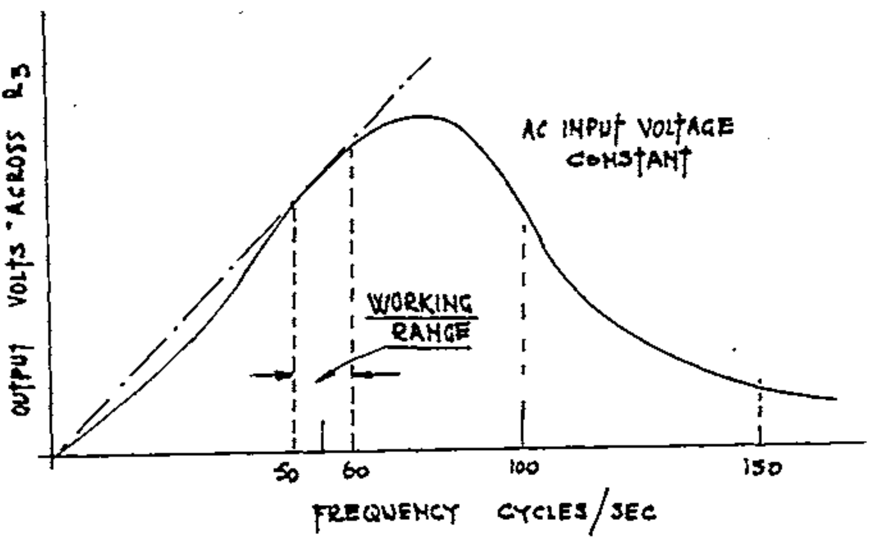
One method of overcoming the difficulty would be to pass the voltage signal from the alternator through a "filter" just as one would strain out unwanted particles from a liquid. The electrical counterpart is also called a "filter" and in this case we want a "low-pass filter" circuit to block all frequencies higher than the fundamental. If the whole of the input is passed through a filter, the components are excessively large.

A more economical way is to filter the control branch only and an added advantage is that the condenser already in the circuit can be made part of the filter. Fig. 7 shows the modified circuit and the voltage adjusting rheostat is now removed from R_3 and placed in the reference branch. If this were not done the adjustment of this resistor would upset the frequency setting of the control branch.

Once we start using a filter circuit we must reckon with its resonance curve. The filter only works because it offers the minimum impedence at its resonance frequency. In this instance we cannot use the resonance frequency itself, but must ensure that the working range includes a point where a tangent through the origin touches the resonance curve (see Fig. 8). It is only in this neighbourhood when the impedence is inversely proportional to frequency that the characteristic of the control branch will match that of the



— FIG 7 —



— FIG 8 —

reference branch. It can be shown that this occurs when the following equation is satisfied.

$$R^2 + 2(wL)^2 - \frac{2L}{C} = 0$$

where R = total effective AC resistance of the control branch.
L = Inductance of the control branch.
C = Capacitance of the control branch.
$w = 2\pi \times$ frequency.

The fine adjustments to satisfy this condition to allow for tolerance in the components is effected by the preset resistance R_4. Once R_4 has been set we must not tamper with the resistance of the branch in any way, hence the transfer of the voltage setting resistance (R_5) to the reference branch.

A characteristic of this type of filter is that it gives slight magnification between the fundamental and second harmonic, but very effective attenuation above the third harmonic. Since the line voltage rarely contains harmonics below the third, which is attenuated by about 50 per cent, this is quite satisfactory.

Temperature Sensitivity

This problem, generally speaking, is solved by using high grade materials coupled with a certain amount of trial and error. During the development stages each component was immersed in an oil bath and its own individual temperature characteristic was examined. Its own self-heating effect was also ascertained. At first the most troublesome component was the saturated transformer (T_1), the saturation flux density of which was found to fall by 0.1 per degree C. rise in temperature. This was reduced to 0.01 per cent per degree C. by using grain oriented silicon steel cores in place of Mumetal. The next components were the rectifiers. With both rectifiers at the same temperature the balance voltage rose by 0.035 per cent per degree C. rise in temperature. This can be compensated for by inserting various other resistors in the circuit, but these reduce the sensitivity of the circuit. The more resistance there is, the flatter do the curves become in Figs. 3 and 4. Resistance has to be reduced to a minimum if we are to get maximum sensitivity. It so happened in this circuit that when the condenser was examined its characteristic almost exactly compensated the rectifiers, so the solution was easy. The resistors are all wound with nichrome wire, which has a negligible temperature coefficient. The effect of ambient temperature on the unit as a whole is to cause the balance voltage to vary by less than 1 per cent over the temperature range 0–80° C.

In conclusion, it is hoped that the first part of this article will give the reader some idea of the principles involved in this circuit. The second part is an attempt to bring out the difficulties of the designer of such equipment, and also to discourage "smart Alecs" from tinkering about with these things unless they thoroughly understand the finer points.

All the components are tropicalized and hermetically sealed where possible. Once the circuit is adjusted by the makers or by a competent repair workshop it should be perfectly reliable.

As regards the set as a whole, like the Magnicon exciter, due to the enormous amplification of the error signal by the exciter system, certain points have to be watched. The brush positions and the state of the commutators on the rotating parts have to be correct. Any maladjustment or dirt has a serious effect on the performance of the machine.

SECOND-IN-COMMAND OF A FIELD SQUADRON

By CAPTAIN T. C. WHITE, R.E.

HAVING read with interest the article on the Regimental Second-in-Command which was published in the *Journal* of December, 1954 (Vol. LXVIII), I feel it might well be followed up with a few words concerning the Field Squadron Second-in-Command.

I believe that most officers have to teach themselves how to become a Second-in-Command of a field squadron. I know of no pamphlet which nicely summarizes his duties and responsibilities; or even more valuable, summarizes the many pitfalls. My aim here is to produce a few wrinkles for those about to become a Second-in-Command. I may even produce a guilty conscience in some who already hold the post.

Some of what I include here may appear to be basic, but far from excusing this, I include it because it is so often the basic things that are overlooked. For instance, how many Seconds-in-Command, or even C.Os., check the actual holdings of vehicles against the vehicle register when they take over a unit? Not many, and it took me eight months to discover that we were shy of a motor-cycle. We still had the frame, which had been carefully hidden away by an enterprising M.T. sergeant. He had used this machine for spare parts, rather than make the soldiers pay for their losses. There is no doubt that the problems of a Second-in-Command now are far more numerous and complicated than they were pre-1939. The reasons for this are: the inexorable advance of paper disease, National Service, and a distressing post-war tendency to work in the afternoons. There are of course other reasons connected directly with the social advances of our time. Whatever the reasons may be, the troop commander about to become a Second-in-Command must prepare himself for an exacting task if it is to be done properly.

Reduced to their simplest terms, the jobs of O.C. and Second-in-Command respectively are Leading and Administration. If we say that Leading includes Policy, Training and Discipline, then the Second-in-Command's job is everything else that happens. The relationship between these two people is all important if the squadron is to work efficiently. What must be achieved is that the O.C. should be relieved of all administrative detail, but at the same time be aware of the general administrative situation within the squadron. Likewise the Second-in-Command should not become too involved in the direction of the squadron as a whole, but still be sufficiently in the picture to be able to take over from the O.C. at short notice.

This is a matter of preventing Administration and Leading becoming watertight compartments, and on the other hand preventing the organization becoming purely a one-over-one set-up. Much of the initiative on this score must come from the Second-in-Command because he sees, or should see, every piece of paper which comes in the squadron. The O.C., it is to be hoped, does not.

With regard to keeping the O.C. free from administrative detail, a certain amount of judgement is required. For example, the O.C. may well be interested in the fact that his wireless sets are to be changed from Mark II to Mark III, but it would be a waste of his time to tell him the same thing with regard to, say, motor-cycle pannier bags. Even worse would be to put in his tray a piece of paper which took three paragraphs to tell him so. This is a straightforward example which would apply to most O.Cs., but squadrom commanders vary, and Seconds-in-Command must suit the supply to the demand. On the other hand, keeping the Second-in-Command in a position to take over the squadron must be looked after by the O.C. Training programmes in particular should be fully explained to the Second-in-Command, because he all too easily becomes divorced from training matters. He should also, as far as possible, be aware of the outline of operational plans and policy matters affecting the squadron. It is easy to slip into the habit of not telling the O.C. enough. What must be avoided at all costs is to allow him to be approached by his senior on a subject about which he knows nothing. In this respect, a golden rule is always to tell him about everything that goes wrong, regardless of how small the matter may seem, and of how efficiently one may think it has been cleared up. It is invariably these little things that come home to roost direct from the C.R.E., and the O.C. must be prepared for them. Similarly the O.C. should always reply with his own signature to any kind of reprimand, and also sign all letters of a policy nature.

Having cut down the paper to a minimum, it is worth considering the method of presenting that which does reach the O.C. What is given to him is either for information or action. Things which are for information only are generally easily recognizable as such, but anything that requires action must be clearly marked. This prevents papers for action merely getting initialled and put smartly into the "out" tray. The thing to avoid here is for the Second-in-Command to put up something that he does not understand. The possibility is that the O.C. does not understand it either, and will hope that it has been dealt with anyway. This sort of thing leads nowhere. I tried it once, and the piece of paper in question went back to the chief clerk with nothing but two sets of initials on it. When the chief clerk, who understood the subject matter quite clearly, politely inquired why I was keeping it on ice, I made up my mind to be more careful in future.

Now to touch on what is probably the Second-in-Command's biggest job of all: that of looking after the squadron equipment and stores. It is here that he is most likely to meet his Waterloo, and in order to avoid this there are a few basic essentials which he might note. He must get a good S.Q.M.S., and must not hesitate to be ruthless with one that is not good. He must be ruthless the first time something goes wrong. It is not worth waiting until there is also a five-pound bill for lost stores, and no one to charge it to. He must learn the rules and regulations himself. This is a very dull business, but it pays in the long run and enables him to talk to the Q.M. in his own language. This in itself is often worth extra rations for an exercise period. He should take care to give his S.Q.M.S. a good staff with which to work. There may be a tendency on the part of the O.C. to get all the really intelligent chaps out to the field troops, where they may in time make much needed section N.C.Os. This must be resisted within reason, because the S.Q.M.S. must have an efficient staff if he is to do his job properly. He must beware of exercises and training camps, because playing at war and peace-time accounting just don't go together. At one end of the string is the C.O. who wants every man in his squadrons out in the field, training ruthlessly for war at every available opportunity. At the other end is the Command Secretary who wants to know why Part V of a travel warrant used on the 7th May was not written off until the 30th July, when it should, of course, have been written off on the 30th June (see G.R.O. 1234 of 1951 as amended by etc., etc.). Somewhere in the middle of all this is the unfortunate Second-in-Command. A happy medium must be arrived at here, but the more the S.Q.M.S. and his clerks are taken away from their ledgers and vouchers, the more things will go wrong with peace-time accounting. The Command Secretary must be treated as a friend and not an enemy. Too many people are afraid of the Command Secretary finding out something that has gone wrong. The right answer is to ring the chap up right away and say, "Look here, I've made the most imperial nonsense over accounting for celluloid shirt collar stiffeners, can you please send someone down to sort it out for me?" He is there to help and his staff are expert at all forms of accounting. A friendly relationship should be cultivated with him, and he should never be regarded as someone who is only trying to catch people out. All stores should be checked as often as possible. A few items should be checked whenever possible, and it is virtually useless putting this off in order to check the whole thing at one sitting, for the opportunity never arrives. Little and often is the cry here, but it is very difficult to do. So much for a few basic facts.

Now for some detail. Take accommodation stores for instance. These are one of the worst headaches, and yet are often regarded as being purely the province of the S.Q.M.S. They should of course be regarded in just the same light as valuable pieces of "1098" equipment; if they are, they don't get lost. Although the S.Q.M.S. holds the accommodation stores on his signature, he in turn must get the signatures of the chief clerk, the M.T. sergeant, the troop officers and the troop sergeants. They in turn will no doubt get signatures from the various N.C.Os. and sappers in charge of the different rooms and departments. This it seems involves vast quantities of paper work all down the line; not only has the M.T. sergeant to look after his M.T., but he must also count his tables and chairs; N.C.Os. and sappers in charge of rooms change so frequently that the system is bound to break down. Well, it is a vast amount of paper work, but we live on paper and every bit that is missed out quickly multiplies itself. If everyone is not made to sign for this sort of stuff, the inevitable result is a loss. Getting all the signatures is only half the battle. The tendency is then to sit back and say "I have a signature for everything, therefore I can be held responsible for nothing." The individual items must be checked at frequent intervals to see that they are there, and whether they require repair or replacement. The responsibility for doing this appears to be that of the person who signed for the articles and who uses them, but the system will never work unless it is also done by the Second-in-Command in conjunction with his S.Q.M.S. He must check all the accommodation stores once a quarter. If the Second-in-Command does not check them the people lower down the line won't check them either, and losses will be discovered too late to make the right person pay the damage. The aim must be to localize each loss as soon as possible after it occurs to ensure that the minimum number of men pay the cost involved.

Checking stores is not nearly so easy as it sounds. Accommodation stores are probably the easiest. At first I used to think it was merely a matter of wandering along, for instance, to the clothing store and turning up gloves M.T. in the ledger, and seeing that the number in the book agreed with the number on the shelf. But no; consider where all the gloves M.T. are, that appear in the ledger. Some are with drivers and will be signed for on an A.F.H.1157; some will be on temporary loan and will be signed for on A.B.108; some may be in a different store altogether awaiting a condemnation board; some will have been issued to replace losses, and will appear on an A.F.P.1954; and there may in fact be a few on the shelf in the store. Quite a job in fact to do really conscientiously. Much of this extra work can be avoided by checking only when the ledger is posted right up to date. This is not always practical, and anyway it is against the principle of little and often. It doesn't frighten the storeman nearly so much either.

To the troop commander the No. 19 wireless set that he has in his scout car merely consists of: a box of tricks, an aerial, two batteries, and a few wires holding the whole thing together. When checking the squadron wireless store as Second-in-Command, however, that No. 19 set becomes a Wireless Station and consists of some fifty separate items, all of which have to be accounted for. Remember the F.A.M.T.O., ammunition, explosive, and mobilization stores; the armoury, and the controlled documents; and the individual little difficulties that each in its own way presents, and one begins to get an idea of the size of the job. So much then for a little detail on the stores side. Appropriate to say something now about the business of paying for the ones that didn't get checked. The big watchword here is Speed. Find the culprit, or culprits, and get the money. Once the thing has been allowed to grow cold, there is a justifiable feeling of dissatisfaction amongst those made to pay. In the case of personal losses of kit by soldiers, the snag is to ensure that the red ink entry in the man's pay book is signed by his troop officer. That is important and is often overlooked by all except the Visiting Paymaster, who is not impressed by such omissions. I find that one extra Orderly Officer per unsigned entry is as good a way as any of keeping the thing up to date. After an exercise, or some event where stores have been used in any quantity, it is a good plan to lay down a deadline by which all stores losses must be reported. Some of these losses may be written off by the C.O.; in some cases a greater amount may be written off by a higher authority. These items must be officially priced and submitted for write-off action. The remaining stores which cannot be written-off must also be priced, the money collected, and paid into the Imprest Account on one of the appropriate forms. A copy of this form supports the removal of the item from the unit ledger. There is seldom any difficulty in paying money into Imprest; it is the other way round that sometimes causes trouble. It is worth while remembering that losses of stores may have to be the subject of a charge, and sometimes a court of inquiry. Much can be done by the Second-in-Command in obtaining really good stores discipline in the unit. A man who knows that he will have to pay on the nail for something that he could have avoided losing, will be a more careful chap in the future.

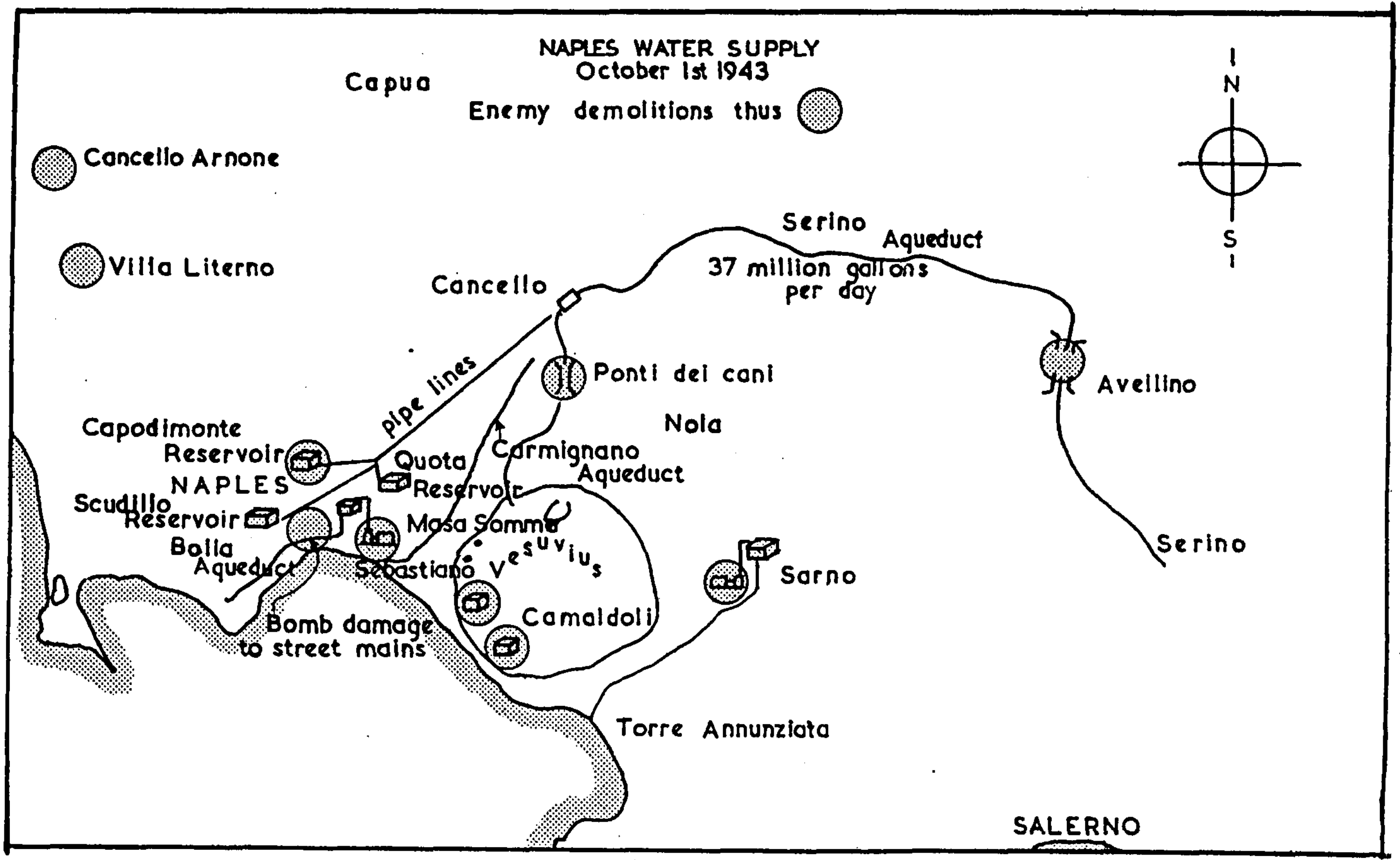
Now let's go into the office and consider Pay and Documentation. Here again one has got to get down to it and learn up the detail. It is the easiest thing in the world for a soldier to get into debt, or fail to receive money to which he is entitled, because of bad documentation. If the Second-in-Command does not learn the detail himself, he can be sure that some of his clerks won't learn it either; and then the trouble starts. It is not an easy job sorting out all the rules and regulations and the dozens of amendments that are always present. Every day there is something new to learn on this subject. The Command Paymaster, the Regimental Paymaster and the Record Office are the people who know all the answers to good documentation, and it is a good plan to keep in touch with them as soon as a snag is met.

In the matter of pay, a great thing to guard against is the soft-hearted pay clerk who can't say "no" to his friends who are already in debt. It is a good plan to get a list each month of all the men who are in debt. If there are more than three or four names on the list, all is not well. The checking of the men's personal documents—a tremendously important item—is never quite as easy as it sounds. To make a really complete check of one set of documents takes about ten to fifteen minutes. If there are something in the order of two hundred men in the squadron, then one set a day must be checked to get through the lot in six months. It is uneconomical in time to do it this way, and six or seven should be done at a sitting, say once a week. How easy it is to get behind! Most of this work should be done by the chief clerk and the pay clerk, but a few personal checks must be made once in a while. A word or two here on the subject of barrack damages would not be out of place. In theory one is not supposed to operate a barrack damage account, as all damages should be paid for on the spot. In practice it is found difficult to work the system at all without running some kind of account. It is not easy for a soldier, or for that matter an N.C.O., to bill his comrades with damage which, in his opinion, could well be paid for by Her Majesty's Government. This entails the Second-in-Command dealing with the problem himself, with the assistance of the S.Q.M.S. and perhaps the S.S.M. The principle should be that the maximum amount be charged to the individual, and the minimum to the squadron as a whole. It is idle and quite wrong to make a general levy with which to pay the D.C.R.E's. bill. It is always a matter of some difficulty to apportion the amounts of bills accurately and fairly, but even this is not half so difficult as actually getting the troop commanders to collect the cash from those concerned.

The organization of the squadron M.T. is worth some consideration. As Second-in-Command one is *ex officio* squadron M.T. officer (although headquarter subalterns have their uses in this respect). However this subject is treated there is always a certain amount of divided responsibility between the M.T. sergeant and the troop officer. The troop officer must be ultimately responsible for his M.T., but there are some aspects of maintenance and documentation which are normally the responsibility of the M.T. sergeant. The M.T. sergeant must be allowed to detail transport for squadron and regimental tasks and duties, but there is not always sufficient available in squadron headquarters for this purpose, and it must be detailed from troop transport. These conflicting requirements must be tied up in such a way that the troop commander does not lose his sense of responsibility towards his transport, and the M.T. sergeant does not feel that he has little or no authority. This is not always easy to attain and is often largely a matter of personalities. M.T. tools always seem to have an extraordinary facility for getting themselves lost. Troop officers must be made to check all tool kits once a month. The Second-in-Command must take the follow-up action to see that the losses are paid for and replaced; and he must also make some independent checks. I well remember becoming suspicious about motor-cycle tool kits at one time, and it wasn't until I paraded every motor-cycle in the squadron that I discovered there was a complete tool kit entirely missing; belonging, of course, to the motor-cycle which had been cannibalized; the rider who had no tools merely borrowing some for his monthly check. Water vehicles are an item that require a lot of attention. They have a mass of equipment that goes with them, which I first learnt about as the result of a hygiene inspection by some water cart pundit. Admittedly, since we obtained all the necessary stuff it has remained in the M.T. store, only to be produced at subsequent hygiene inspections, but now I know what ought to be there.

The F.A.M.T.O. account warrants considerable personal attention. It is full of so many small and attractive items, such as sparking plugs and bulbs, which just refuse to account for themselves. Continual stocktaking here is essential, and one way of doing it is to get the orderly officer to check a given number of items each day. The important thing to remember about all these accounts, is that when they get sent off to the Command Secretary for audit (as they normally do once a year), they must have with them a record of a complete stock check. Indeed one has to sign a most unpleasant document which says that "I personally certify . . ." that the stocks remaining in the store are those as shown in the balance on the ledger.

Well, those are some of the things that concerned me when I first started the job, and I could go on for pages more. I have not mentioned the intricacies of Part II and III Orders, P.O.L. accounting, War Office Controlled Stores and a host of other things. One thing I must say about P.O.L. accounting is that I once made the error of drawing some petrol (20 litres of it) from a R.A.F. station. This tricky inter-service transfer involved no less than nine copies of a voucher, four letters, and twenty-six officer signatures. It is things like that which make the job an amusing one. I think the urge to write this came from a slight anger at having learnt the hard way, and in the hope that we may sometime see a small pamphlet summarizing the more important duties of the Second-in-Command.


NAPLES WATER SUPPLY
October 1st 1943
Enemy demolitions thus
Capua
N
S
Cancello Arnone
Villa Literno
Cancello
Serino
Aqueduct
37 million gallons
per day
Ponti dei cani
Avellino
pipe lines
Capodimonte
Reservoir
NAPLES
Quota
Reservoir
Carmignano
Aqueduct
Nola
Scudillo
Reservoir
Bolla
Aqueduct
Masa Somma
Sebastiano
Vesuvius
Camaldoli
Sarno
Serino
Bomb damage
to street mains
Torre Annunziata
SALERNO

WATER

By LIEUT.-COLONEL H. D. STOW, M.C., E.R.D.

AS one takes-off from London Airport and the aircraft climbs and turns, one sees below the Staines Reservoirs like miniature lakes penned about by suburban London, and one realizes the vulnerability of our water supplies from bacteriological and nuclear weapons.

In any future war the physical damage to a community's water supplies in terms of destroyed pumping stations and broken water mains from a single attack may far exceed that ever known during the last war, and there would be the added serious complications due to lack of water for fire-fighting, decontamination washing, and sewage. The subtle danger, however, is the far reaching contamination of exposed impounded water supplies and catchment areas many miles from the scene of devastation. The bulwarks of defence may well be centred about our village wells and industrial boreholes.

To take some measure of the future, one must turn back thirteen years to the savaging of Naples by the Germans as they retreated before the British X Corps towards the Volturno. The popular *Military History of the Second World War* casually records that the Neapolitans had no water for three weeks because the great city aqueduct was cut in seven places, but to the Sapper Officer Reconnaissance party with a detachment of King's Dragoon Guards that entered the city on the morning of 1st October, 1943, this was a simplification of the facts.

The coastal outskirts of the city lay in ruins, rubble filled the streets, an ominous silence hung about the gaunt buildings, broken only by an occasional rifle shot. Suddenly on entering the Piazza Guglielmo Pepe, there emerged an excited and motley band of partisans, each armed with weapons from sabres to sub-machine guns and festooned with bandoliers of small arms ammunition and grenades. It was a tense moment of mutual recognition, then in an almost Gilbertian manner the partisans swarmed over the K.D.G.'s armoured cars, waving in the general direction of the enemy. The British O.C. "Cared for none of these things" and had some difficulty in persuading their leader that his immediate objective was the Municipio and was obliged to leave his perplexed allies, having obtained the services of a guide.

The excitement of these few minutes must have been witnessed by many unseen inhabitants hiding in their tenements, as they now ventured out and went about their daily tasks. Some women with ladles, came out into the streets to scoop up water from puddles, others prised open sewer manhole covers and bailed out the storm water, for although the city had been without tap water for some days, a providential thunderstorm the evening before had been followed by torrential rain.

At the Municipio, a few of the civic dignities returned, others were sent for, but some had been taken as hostages by the retreating enemy, who revenged themselves for the Italian Armistice by deliberately disrupting the water, electric, gas and transport services. What could not be taken away was destroyed. All food stocks were taken and as a parting jest, cunning delayed-action mines were left in the Post Office and other main buildings to kill without discrimination.

The City's Water Engineer reported an alarming and desperate water supply problem. The main Serino Aqueduct which normally supplied 37 million gallons a day to Naples and the area around Vesuvius was cut. No water had flowed into the city's reservoirs for two days.

Capodimonte the principal reservoir of some 17 million gallons capacity had been mined. The 13 million gallon Scudillo reservoir and the 2 million gallon Quota reservoir were both believed to be still intact but holding less than half-a-day's supply.

It was thought that the Germans were not aware of the existence of the two smaller reservoirs, but, if they were, to hoodwink the Germans into believing that they had completed their destruction, the reservoir attendants had closed the supply valves.

Of other possible sources of water supply, there existed the Carmignano Aqueduct which at that time of the year was dry, and the Bolla Aqueduct which was an industrial supply for street washing and public fountains. The Bolla Aqueduct supplied 3¼ million gallons a day, which was pumped up some 150 ft. to a high level reservoir from which it flowed along the sea front to the "Riviera di Chiaio", but not only was there no electricity for the electric pumps but the water required chlorination for domestic purposes.

The City's Water Engineer summed up the total water assets at 1 gallon per head for a limited period, which could only be supplied to those who could go to the undamaged reservoirs to get it for themselves.

The following day, a British Wellboring Troop made a reconnaissance for all possible "private" water supplies. Deep boreholes, unknown to the civic authorities, were located at a refrigeration plant, a bank, a flour mill, a brewery and a laundry, and in the Piazza Municipio itself.

That same day a water-point was set up at the refrigeration plant supplying some 6,000 gallons per hour to the over-crowded area of the docks. Within three days other water-points were set up to supply 80,000 gallons per day.

Meanwhile the U.S. Army engineers were busy establishing water-points at the two undamaged reservoirs and the Bolla Aqueduct, and setting up "dry" water-points, or centres of water redistribution in those parts of the city farthest from the "wet" water-points. Both "dry" and "wet" water-points were as used during the desert campaign for forward can filling, but they were inadequate to cope with the large crowds of Italians who swarmed at the taps armed with every conceivable receptacle from bottles to bath tubs.

The water was pumped into a 3-in. header pipe, raised about 2 ft. 6 in. above pavement level with a row of taps spaced at 3-ft. centres. For such crowds the taps were too close together to provide for an orderly "up" and "down" queue to each tap. The queues broke ranks and there was some disorder. Women kicked and pulled one another's hair and many bottles were broken. At one water-point the British corporal and three sappers restored order by their example of patience and good humour to win the confidence of the crowds when rifle butts and revolver shots had failed.

By the end of October good progress had been made in restoring the City's water supply; the Germans had been pushed off the Serino Aqueduct. The Americans had repaired the break in the main aqueduct gallery near Avillino, 40 miles away, and the civilians had repaired the Capodimonte reservoir and the major bomb damage breaks in the street mains. Water supply was on tap for some hours each day but when the water was first turned on to supply, it was found that some domestic taps were polluted due to the growth of Bact. coli in the dry tap-washers. Those thirty days had been an anxious time. The city had stunk. The Luftwaffe had bombed the city almost every night, and there had been no water for fire fighting. Fortunately the typhus epidemic which had broken out was successfully countered, as every ragamuffin of both sexes was dusted with D.D.T. from head to foot.

By 12th November, the water supply in the area around Vesuvius was restored to 3 million gallons a day. A 16-in. C.I. main was rebuilt by the Wellborers over a 200-ft. gap at Ponti-dei-Cani. Improvised repairs were carried out at the high level reservoir at Camaldoli which had been mined and the low level reservoir was cleared of the prepared charges and made safe. It is interesting that the Germans, having lit the fuse, retired, but the demolition failed due to the humidity in the reservoir and the fuse petered out only a few feet from the initiating detonator.

The Wellboring Troop detachments moved up along the L. of C. and installed Loco-Filling-Points and elevated storage tanks along the defunct electrified railway for the steam locomotives which required about 5,000 gallons of water per hour of work in double-quick filling time. Most of the depots and stations were rubble and tangled steelwork, but the rolling stock in some cases only booby-trapped and so it was not unusual to see small parties of Sappers with handfuls of ballast from the permanent way throwing stones at suspected charges.

Within seven weeks the water supply was restored, except for some losses in undetected broken mains and in some demolished buildings, to the whole city of Naples and the region around Vesuvius with a population equal to that of Birmingham. It was an achievement due to the efficient co-operation between the civilian water engineers, British Sappers and U.S. Army Engineers. There could not have been a better spirit of unselfishness between the various civilian authorities in the pooling of their resources of C.I. pipes, valves and even pumps, for none of these stores were likely to be found elsewhere in liberated Italy.

Life, slowly at first, began to flow again into an almost dead city. The Royal Navy and Americans tidied-up the docks, restored the electric power, trams began to run again and there was electric light. With the enemy now sheltering behind his Winter Line some forty miles away the shutters came down and the shops, cafés and bars opened for business.

All should now have been well and the new year of 1944 heralded with increasing confidence, but the months ahead brought nothing but disappointments and frustration in the maintaining of the water supplies that had been regained with such enthusiasm and co-operation.

In the half starved city, inflation ran wild. The economic conditions were fantastic. There was no white market, only a pernicious black market and racketeers. Meat cost 9s. a lb. Butter 20s. a lb. A 'teen-age bootblack on the streets cleaning allied boots earned the equivalent of 50s. a day compared with a fairly senior Italian Foreign Office official's salary of £15 a month. It was a struggle for existence and such food that money could buy was not sufficient a diet for a man to do more than a few hours work a day.

It was not surprising, therefore, that the water companies employees should have asked for a rise in pay, or to be paid in food, but the Allied Military Government had "frozen" the rates for public services and so the water companies found themselves rapidly becoming insolvent.

Even before this difficulty was resolved, the managing director of one of the companies was thrown into jail with a sentence of ten years imprisonment over his head for being in possession of U.S. Army tyres. The Germans before leaving, had stolen all this company's vehicles but had obligingly left the managing director his car, having first removed all the tyres. He needed his car, the only vehicle left with the company to maintain and supervise the whole of the water supply system of pumps and mains from Sarno to Torre Annunziata. He had done his best and had bought some tyres, where else, but from the black market?

It was unfortunate that this water engineer should have chosen the same day as a senior American General to visit the Allied Military Government offices at the Municipio. The General's car was jacked up and the wheels stolen from under the noses of the military police. Near by stood the Water Engineer's car and he had no idea of the awful origin of his tyres, but the U.S. Military Police were out for blood.

Wellborers turned advocates was a new rôle. Adjustment of the water rates was granted and the crisis was just avoided. The Military Tribunal that tried the unfortunate water engineer, discharged him with a fine and a compliment for his sense of civic duty but kept the tyres and the car.

It was now Wellborers turned bailiffs. There had begun a general influx of units. Every empty building was occupied. Each unit proceeded to help itself to water. Some units tapped the main Serino Aqueduct, others tapped the main pipelines. One unit tapped a 600-ft. head main and then complained of leaky taps. It is not unusual in Italy in normal times for water in the country districts to be on tap only for certain hours of the day so as to recharge the reservoirs overnight, but some commanders demanded a 24-hour service. The water engineers were humiliated; one, who had proved his loyalty, in frustration blurted out that he would sooner serve the Germans. The Allies he said, ignored him and after helping themselves to his water, made impossible demands. The Germans, when they needed a service, sent for him and told him what was wanted. If he needed transport, it was provided. If he needed labour or materials it would be provided. Anything that was wanted to do the job was provided, but if the job was not done expectancy of life was short, but he preferred to do business that way.

Amidst all the difficulties, nature herself took a hand. Vesuvius, which had been grumbling for some time broke into eruption. A stream of lava flowed down from the crater destroying everything in its path and cracking houses like nuts. The lava cut the pipeline between the villages of Massa Somma and Sebastiano and only halted 80 yds. from the main Vesuvius pipeline. The ash which covered a wide area, severely damaged many aircraft on near-by air strips and the insidious gas spreading through the fissured limestone and basalt silently killed those that took shelter in their caves from the enemy nightly bombing raids.

On looking back over one's shoulder on leaving the city of Naples, there was to be seen for the benefit of newcomers, a sign across the road that read "If she is game, she has got it". One could only ponder upon the ambiguity of the statement and think of that unhappy city.

The moral of the story is a plea for a closer liaison between military and the civilian authorities responsible for the maintenance of public services, particularly the water supplies.

Sapper officers, commanding field units, at home or overseas, should personally know the civilian civil engineers in their areas and have a general knowledge of the distribution system of water, electricity and gas.

Water supplies are too easily taken for granted. Units with a nodding acquaintance of R.E. Works Services, might well understand the channels by which the newest recruit receives his pay and rations but have not the faintest idea of how the water got into the cookhouse pipes. Even on field exercises most units use their water trucks as a mobile tap. A water truck does more running about in an operational area than any other vehicle.

ARTICLES FOR THE R.E. JOURNAL

1. Articles for the "R.E. Journal" will be typewritten and submitted in duplicate, one copy being the original.

2. Line drawings must be in black ink. Ink tracings on linen are very suitable. All lettering must be clear and bold to allow for reduction in size when reproduced. Scales will be drawn and not worded.

3. If tracings are submitted one print should be sent for the duplicate copy.

4. Photographs should be on glossy prints, and no writing should be on the photograph itself. Any reasonable size print may be submitted.

Not more than four photographs can normally be reproduced with any article. More photographs may be submitted and the Editor will make a selection.

5. Contributors to the Journal are reminded that under Queen's Regulations any information of a professional nature acquired while travelling or employed on duty is regarded as the property of the War Department and will not be published in any form without the previous sanction of the War Office.

It is suggested that prospective authors should read carefully Queen's Regulations, 1955, paragraphs 679 and 680.

6. War Office sanction to publish can be obtained, if desired, by the Editor, but authors must obtain a statement from the authority under whom the applicant is immediately serving that such authority has no objection to War Office permission being applied for.


Brigadier-General T A H BIGGE CB CMG

MEMOIRS

BRIGADIER-GENERAL T. A. H. BIGGE, C.B., C.M.G.

"TOMMY" BIGGE was born on 8th December, 1866, the son of Major-General T. S. C. Bigge, C.B.

Educated at Oxford Military College and the R.M.A. Woolwich, he was commissioned in the Corps in September, 1885. After the usual course at the S.M.E. he was posted to the 26th Field Company at Shorncliffe in 1887, and two years later went to the 20th Fortress Company at Gibraltar.

He was promoted Captain in 1895, and after doing a Musketry Course at Hythe in 1896, he was appointed Adjutant of the Training Battalion at Chatham, and later Staff Officer at the S.M.E.

In 1901 he was sent to Bermuda as Staff Officer for the Prisoner of War camps there, and the following year became Assistant Military Secretary and A.D.C. to the Governor.

He was promoted Major in 1903, and returned to the U.K. in 1906 as S.O., R.E. to Chief Engineer, Plymouth Defences. Promoted Lieut.-Colonel in 1910, he was appointed O.C. Depot Battalion at Chatham, and the following year O.C. Training Battalion, also at Chatham, where he was serving at the outbreak of war in 1914.

He continued to serve at Chatham until August, 1915, when he went to France as C.R.E. 14 Division. He was invalided home the following year, and in September, 1916, was appointed A.D.F.W. at the War Office, having been promoted Colonel with seniority, June, 1914.

In March, 1917, he was appointed A.A.G., R.E., and was granted the temporary rank of Brigadier-General. He held this appointment till he retired in September, 1919.

For his services during the war he was awarded the C.B. in 1916, and the C.M.G. in 1919. He was also appointed a Commander of the Crown of Belgium.

In 1889 he married Lucy Katherine Bourne, who died in 1946, and he is survived by his three daughters.

Tommy Bigge was a great cricketer and a great golfer, and represented the Corps in both games on many occasions. R.L.W., who served under him when he was Adjutant of the Training Battalion and knew him well in later years, writes as follows:—

"I first knew Tommy Bigge in 1896, when I completed my S.M.E. Course and was posted to the Training Battalion; then commanded by H. W. Renny-Tailyour, the great cricketer. For a young officer, no one could have had a better Adjutant under whom to serve, strict, but always ready to help either a young officer or a young N.C.O. He played a lot of cricket, representing the Corps on many occasions, as well as playing for the Free Foresters. His cheerful determination was an inspiration to any side, either in batting or fielding.

"As a young man at Gibraltar, he rode for the Corps in the Calpe Hunt Cup team, a cup won many times by the Corps.

"To sum up—whether at work or at play, he put his whole heart into it."

J.C.W. also writes about his golf.

"No account of Tommy Bigge would be complete without reference to his unique contribution to R.E. Golf.

"He played for the Corps in the Annual R.E. *v.* R.A. matches at Royal St. George's, Sandwich, no less than ten times; in 1898, 1899, 1901, 1907, 1908, 1909, 1910, 1911, 1912, 1913, between the ages of 31 and 46. As there was no match in 1900, and he was serving in Bermuda from 1902 to 1907, and he was chosen to play for seven consecutive years on his return, this is a remarkable achievement. In addition, in March, 1926, at the age of 59, he played in an unrecorded match against the Gunners at Cobham, the official encounter taking place as usual at Sandwich the following month.

"In June, 1925, an Annual General Meeting was held at which the R.E. Golfing Society was first formed, probably at his instigation.

"At this meeting, Tommy Bigge, and his brother Lieut-Colonel G. O. Bigge, presented to the Corps the Bigge Snuff Box, to be played for annually at the Corps Autumn Meeting. The winner, the lowest scratch score over two rounds of eighteen holes, becomes the R.E. Champion for the year.

"As all Sapper golfers will know, this much-treasured trophy consists of an antique gold snuff box, mounted on a polished ebony stand, round which are plaques on which the names of the winners are engraved. Within the stand is a drawer in which lies a short history of the snuff box. For travelling, the snuff box is housed in the drawer, the whole trophy reposing in a case.

"This handsome gift has done more for the encouragement of R.E. golf than its donors could probably ever have foreseen.

"Bigge was elected President of the R.E. Golfing Society for 1933.

"After he had given up active golf, he continued by his presence at meetings to inspire new blood and further the keen spirit of golf. A true golfer, whose name will live as long as R.E. golf exists."

Bigge died at Torquay on 30th December, 1955, at the age of 89, and so passed on another well-known and much loved member of the Corps.

The President R.E. Golfing Society for 1955 was represented at his funeral.

BRIGADIER-GENERAL CHARLES GODBY, C.B., C.M.G., D.S.O.

CHARLES GODBY, born on 31st October, 1863, was the son of Major-General Joseph Godby of the Royal Artillery. On passing out of the R.M.A. Woolwich he was gazetted as a Lieutenant in the Royal Engineers on 1st October, 1882, and on completion of his course at the S.M.E. was posted to the 29th Company at the Curragh in 1884.

Early the following year he was posted to the 24th Company, with the Expeditionary Force to Suakim, and was present at the engagements at Hashin and Tofrek. On the conclusion of activities in the Sudan, the company went to Cairo, and Godby remained with it till 1889, when he was posted to the Egyptian Army, first in the Sudan and later in Cairo, on the staff under Brigadier-General Sir Henry (later Field-Marshal Lord) Kitchener, and was present at the battle of Toski in 1889.

For his services in the Sudan, he received the Medal with two clasps, the Bronze Star and the Order of Mejidieh 4th Class.

In 1895 he returned to the U.K. and was posted to Plymouth, where he remained in various capacities until posted to Bermuda in 1903.

He had been promoted Captain in 1891, Major in 1900, Lieut.-Colonel in 1907, when he was appointed C.R.E. at Chatham, and Colonel in 1911.

In 1913 he was appointed to be Chief Engineer, South Coast Defences at Portsmouth, where he remained on the outbreak of War in 1914. He went to France as Chief Engineer, 1 Corps in April, 1915, and was present at the battles of Aubers Ridge and Festubert in that year. In September, 1915, he was posted to XII Corps on its formation, but shortly afterwards was transferred to II Corps, still as Chief Engineer.

With the II Corps he served through the battles of the Somme, 1916, the pursuit to the Hindenburg Line, and the third battle of Ypres in 1917, and finally the advance to victory in 1918.

He gained the D.S.O. in 1917 for the courage and determination he displayed when hostile shellfire blew up a Corps ammunition dump. There were many casualties and he organized parties to remove the wounded, and with another officer he extricated two officers who had been buried by a fall of debris. All this was accomplished amid blazing ammunition and frequent explosions.

In 1917 he was appointed C.M.G., and C.B. in 1918. He was also awarded the French Legion of Honour and the Belgian Croix de Guerre.

He was twice wounded and four times mentioned in Despatches, and retired in 1919 with the rank of Brigadier-General.

He married in 1885 Miss Emmeline Hamilton-Jones, the daughter of Mr. T. M. Hamilton-Jones, D.L., of Moneyglass, C. Antrim, and had one son and four daughters. His wife died in 1926.

After Godby retired he went to live at Rowledge near Farnham, where he took a great interest in local affairs and served on the Farnham Urban Council for twenty years, including three years as Chairman. He also served on the Surrey County Council for twelve years, and for a similar time as Chairman of the Farnham County Hospital Committee.

He was a very devout and keen churchman, and was Treasurer of the Church for over twenty years. At the age of 89 he bicycled to Buckhorn Oak (2½ miles each way) to take the services on Sunday evenings.

His chief recreations in his younger days were tennis, cricket, shooting and fishing (he fished until he was nearly eighty), and latterly gardening. So, at the age of 92, passed on one of the older members of the Corps, although not quite the oldest.

C.C.P.

BOOK REVIEWS

HISTORY OF THE SECOND WORLD WAR
THE MEDITERRANEAN AND MIDDLE EAST, Volume II

By MAJOR-GENERAL I. S. O. PLAYFAIR and a small team of assistants
(Published by H.M. Stationery Office. Price 35s.)

This is the second of the six projected volumes dealing with the sea, land and air operations in the Mediterranean area and the Middle East. The first of these was reviewed in this *Journal* in June, 1954. The present volume covers the period from roughly March till October, 1941. A glance at the chronology of the events that took place during these eight months (pp. 326–31) shows clearly that they were months packed to overflowing with problems not only for the three Commanders-in-Chief and their staffs but for the historian charged with recording them. During much of the period five separate campaigns were being fought, each of them on land and in the air, and all the time operations at sea were playing their vital part, while politics, not only Allied and Axis but neutral and semi-neutral, were for ever complicating the picture. It would have been only too easy for the authors to have produced a hotch-potch of facts that confused their readers and made the story quite indigestible. They have written a book, not only as exciting as many a thriller, but an authoritative history that clarifies the events of 1941 in a way that seemed hardly possible to one who was there during that confusing and threatening year.

It was a year that contained such bitter disappointments and so many dangers, but a year that left us with our vital possessions intact. The reasons for the spring disasters in Cyrenaica, Greece and Crete are given fully and with fairness, and can be summed up as "too many jobs and not enough men or tools". On the other hand it is now quite clear that the Axis paid so dearly for their successes that Hitler was not prepared to reinforce these costly diversions at the expense of his main attack upon Russia. It was his heavy losses during the capture of Crete against its gallant defenders that certainly dissuaded him from repeating the dose against Malta and Cyprus, and from occupying Vichy Syria and Iraq.

It is lucky indeed that the Axis powers did not follow up their successes, for the Middle East forces were strained to very near breaking point. The heavy share of this strain that was borne personally by the Commanders-in-Chief is perhaps the main theme of the story. The assistance that they were given by the Chiefs of Staff and by the Prime Minister himself was very great, and many of his personal cables were invaluable; some were not. The few carefully worded paragraphs devoted to this matter show that the authors have formed the opinion that Middle East difficulties (especially administrative ones) and the steps that were being taken to overcome them were not always fully appreciated. All three services, German as well as British, were slow to recognize the importance of maintenance matters in modern war. It was the fact that this importance was realized sooner in Egypt than at home that led to the endless "teeth and tail" controversy. The Prime Minister's appointment of an Intendant General did little to help, but by eventually granting General Wavell's request for a resident Minister of State he did much to ease the burdens carried by the Commanders-in-Chief, though no one could shorten the "tail". In this connexion it is interesting to learn how often it was that Rommel's streamlined forces were held back by maintenance troubles, and one is tempted to wonder how he would have fared had he had a far better administrative set-up in Africa. Perhaps he could never have got it there, for thanks to our ships and aircraft his shipping losses on the short sea-route were very heavy indeed.

In a work of this scope much space must be devoted to this higher control from Whitehall and of course to politics and strategy, but the battle stories of the sea, land and air have not been squeezed out, and, being so well told, they are easy to follow and fun to read. As was the case with the first volume the style is polished, the lay-out and printing very fine and the maps a joy. The photographs are a little disappointing, but cameras were very unpopular in this theatre and films almost unobtainable. A really rewarding book. May this standard be maintained!

It is perhaps permissible to add that the authors' opinion that General Wavell was "one of the great commanders in military history" will certainly be endorsed by those who had the honour to serve under him.

E.F.T.

SIX YEARS OF WAR
THE ARMY IN CANADA, BRITAIN AND THE PACIFIC

By Colonel C. P. Stacey, O.B.E., C.D., A.M., Ph.D., F.R.C.S.

(Published by Edmond Cloutier, C.M.G., Queen's Printer, Ottawa, 1955. Price $3.50.)

This book is the first volume of the Official History of the Canadian Army in the second World War. It covers all its activities except the campaigns in Italy and North-West Europe, which will be published later in separate volumes. A fourth book will deal with the broader aspects of Canadian military policy, particularly co-operation within the Commonwealth and with Allies.

Colonel Stacey begins his history by reminding his readers of the great truth that without being military, the Canadians are a warlike people. Thus after their truly prodigious exertions in Europe in the first World War, they reduced their army to much the same small size that it had been in 1913. In 1932/3 after the great slump, the money spent on defence sank to less than fifteen million dollars, which was a figure truly insignificant for a country of the size and importance of Canada. Yet for all that, in 1939 Canada was better prepared for war than she had been in 1914. This was due for the most part to the unremitting and often thankless labours of successive Ministers of Defence and of the senior regular soldiers of the Permanent Active Militia. Amongst these was the dominating figure of General A. G. L. McNaughton, who perhaps more than any other man, saw to it that the great traditions of the Canadian Expeditionary Force of 1914/18 were handed on intact to the Canadian Army of 1939/45.

The great variety of the tasks which fell to the lot of Canadian troops during their six years of war will surprise even the military reader. He will specially welcome the careful and most unbiased studies of Dieppe and Hong Kong, about which most of us are woefully ignorant. They throw new light on enterprises where the British higher conduct of the war fell below the general level of excellence, which on the whole it managed to maintain. The frontal attack on Dieppe seems to have been ill planned in respect of the covering fire, which such a hazardous operation clearly required. Nor perhaps did the tanks, launched against seawalls and concrete street blocks, have a fair run for their money. Although Dieppe proved to be a very costly diversion, much was learned from it to the profit of the Allied armies, which two years later were destined to land so triumphantly on the open beaches of Normandy.

When the expedience of reinforcing Hong Kong first cropped up in January, 1941, Mr. Churchill commented forcibly "If Japan goes to war with us, there is not the slightest chance of holding Hong Kong or relieving it. Instead of increasing the garrison, it ought to be reduced to a symbolical scale." Later on he allowed himself to be drawn from this position and two Canadian battalions were sent there in October, 1941. The reasons for his second thoughts are examined carefully. They seem to stem from the ineptness of British Military Intelligence in the Far East, which underrated the competence of the Japanese army and misappreciated the probable objects of the Japanese military plan. The two Canadian battalions and their Brigadier Lawson fought with great gallantry. The Brigadier was killed fighting it out in the open at the key point of the island. Of his troops, 557 out of the original 1,975 never returned to Canada.

Amongst the many other places to which, for one reason or another, Canadian troops were sent, the island of Kiska in the Aleutians is perhaps the most interesting. There, for the first time in history, a Canadian formation, organized on U.S. Army lines, operated with an American division under U.S. High Command. The arrangements worked admirably but the blow hit only the empty air. The Japanese garrison had wisely vanished into the mists and fog of the Northern Pacific a week or so before.

Six Years of War is admirably documented, mapped and illustrated. Its judgements are set down soberly and without bitterness. One senses the great position which Canada has acquired in the New World.

B.T.W.

THE APPLICATIONS OF THE THERMONUCLEAR EXPLOSION

By CAMILLE ROUGERON

(Published by Editions Berger-Levrault, Paris. Price 600 francs)

This book, in French, has just been released by the "Editions Berger-Levrault", 5 Rue Auguste Comte, Paris.

The author Camille Rougeron, is a highly cultured man and a very experienced technician. This work, like his previous ones, has a scientific basis from which arise forecasts on the probable uses of thermonuclear explosions in the future.

Of the book's 300 pages, the first ten describe some of the difficulties associated with the development of the H-Bomb. Then follow almost sixty pages giving comparisons between the effects of the atomic and thermonuclear weapons—those of blast, radiation, and heat from explosions in the air, on the ground, and under-water.

Rougeron then asserts that, for the same effects, the reactions of fusion are several hundred times less expensive than the reactions of fission, and further that there is no limit to their power. However, he considers that for military purposes at the present time the 60 Megaton bomb is the most suitable. Its explosion in the air at a height of 75,000 feet would destroy all buildings above the ground within an area of radius 80,000 yards.

The second part of the book deals with peaceful applications of the explosion of fusion, and is no less interesting than the first. It predicts that humanity is to reach an astounding era of economic development under these applications. The "old" reactions of fission are already out of date. Various uses of the explosion of fusion are then considered.

In the field of thermonuclear hydraulics, huge craters formed by underground explosions could be made to prevent irregular rivers from overflowing periodically. Furthermore these craters could be applied to the irrigation of vast areas of arid land, and to the generation of electricity at less cost.

By thermonuclear climatology, rivers such as the St. Lawrence and the Volga, which are normally frozen in winter, could be made navigable throughout the year. In addition, the climate of vast areas, which are now frozen wastes, could be altered by the warming up of lakes and seas, and the fission of ice fields could be used in the production of electricity. In the latter respect, the author calculates that a glacial power station of 2,500,000 Kw. in Greenland would require the explosion of a 60 MT bomb to initiate its operation, then one of a 20 MT bomb each year to keep it running.

Thermonuclear energetics would allow the production of abundant and cheap electrical power by the use of "under-ground boilers". These are vast camouflets filled with water which would be kept boiling for a long time by the heat liberated by the explosion.

Even in chemical industries (water softening, production of chemicals, etc.) and in extractive industries (coal, ore, petroleum) nuclear explosions could be used to give great improvements.

The last hundred pages of the book are concerned with land, sea, and air warfare. It is asserted that present heavy equipments (guns, tanks, ships and planes) are no longer necessary. They could be displaced by thermonuclear missiles coated with cobalt or with sodium 24 of fifteen-hour period.

Only twelve of these bombs would be required to destroy all the crops in the Ukraine or Western Europe, only five to devastate the Ruhr. Weapons transported by free balloons could cause vast areas of death below them. Defensively, barriers could be established with thermonuclear mines charged with activated sands or granulated metal, guaranteeing protection to the defender.

For naval warfare, the author considers that the only answer is the use of deep-water submarines carrying fission missiles.

In the air, heavy bombers and interceptors are obsolete. Fighter bombers capable of carrying the new missiles as well as light planes and helicopters must be developed. However, the best aerial use of thermonuclear weapons will be intercontinental ballistic missiles launched from the ground or from the air.

Rougeron's book will probably call for reservations in respect of some of its statements and predictions, but it is plainly written and arouses the readers' interest by the magnitude of its views. E.J.L.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

(January, 1956. Published by Concrete Publications Ltd. Price 15s.)

Concrete Publications Limited (publishers of Concrete Series books) celebrate the fiftieth anniversary of their monthly periodical by reviewing in this issue the progress of concrete construction throughout Europe, U.S.A., Scandinavia and the U.S.S.R. The articles, which are well illustrated, are written by the leading authorities in the countries concerned, and range from expanding cements in France for use in self stressing concrete, to concreting at $-35°$ C. in the U.S.S.R.

The articles, though taking pride in past achievements, stress the need for further improvement and research, which may be summed up by quoting the article by Henry Lossier.

"Concrete of low tensile strength is an incomplete material that it is necessary to reinforce or prestress. When we have binders which have some of the qualities now lacking, the use of reinforcement will diminish."

A.J.L.

TECHNICAL NOTES

CIVIL ENGINEERING

Extracts from *Civil Engineering*, November, 1955.

Measuring the Moisture in Concrete Aggregates

As a result of the increasing interest shown in concrete quality in recent years, many methods have been devised for measuring the moisture content of the aggregates. These can be classified as follows:—

(*a*) Desiccation methods in which the sample is dried by heating, by burning or by the addition of calcium carbide.

(*b*) Displacement methods in which the volume of the sample of moist aggregate of known weight is determined.

(*c*) Dilution methods in which the changes are determined in the properties of a suitable liquid when the wet aggregate is mixed with it. The properties which have been measured are the strength or colour of chemical solutions, or the specific gravity, or refractive index of the liquid.

(*d*) Electrical methods in which the electrical resistance of the moist aggregate is measured.

The article is well illustrated and describes the various methods tested and the apparatus used. The following conclusions can be drawn from the tests to compare four displacement and two desiccation methods:—

1. The most accurate methods are the buoyancy meter and the direct drying method, both of which determine the centre of the moisture content to within about plus or minus 0.4. The other methods gave readings accurate only to about plus or minus 0.75 per cent. Differences between methods in each of the two groups were not significant.

2. The accuracy of the buoyancy meter was increased when it was used by any one operator, the percentage moisture content being determined to within about plus or minus 0.3. The accuracy of the other methods was not affected by using different operators.

3. All the meters were simple enough to be used by semi-skilled or inexperienced labour without any loss of accuracy if clear and simple step by step instructions were provided.

4. Of the two more accurate methods the buoyancy meter required less time to make a determination than would the direct drying method except with the driest samples. For samples with under 1 per cent of moisture the time taken was just over four minutes for both methods, but for samples with a moisture content of 7½ per cent the time required for drying was nearly doubled. The time required for the buoyancy meter method was independent of the moisture content of the samples.

The article describes and gives results of each test carried out and the type of tests which are as follows:—

The Pycnometer
The Steelyard Moisture Meter
The Syphon Can Method
The Buoyancy Method
The Proprietary Gas-Pressure Method
The Direct Drying Method

Prestressed Precast Arch Frames

There is an interesting article illustrated with excellent photographs and drawings of a site of 10 acres just being developed at Denton, nr. Manchester, to provide a factory for precast concrete, and offices and workshops for a reinforced concrete engineering firm. There are to be fourteen casting beds 150 ft. long, each containing two moulds for floor beams, with provision for prestressing on a long line system, although it would be possible to also use the beds for normally reinforced beams.

The frames for the building consist of twenty-two precast elements; fourteen identical elements 6 ft. long by 15 ft. wide, together with two end blocks to form the arch itself. There are three V-shaped elements in each column. Four prestressing cables form the tie between the springings of an arch, and there are four external cables to each column. These column cables are anchored at the top of the corner element between arch and column and at the bottom in the *in situ* base of a column.

The frames are designed to carry the roof loads, plus fourteen 1-ton loads from the monorail tracks. The maximum stresses in an arch due to working loads, are extremely low, being about 350 lb./sq. in. in compression or tension.

Extracts from *Civil Engineering*, December, 1955.

PREFABRICATED CONCRETE STRUCTURE FOR A NEW IRON FOUNDRY

A new iron foundry at Nuneaton is claimed to be the largest prefabricated concrete building ever constructed in Britain. Built to store and process moulding sands used in foundry work it covers some 200,000 sq. ft. of building. The largest span is 67 ft. wide and is 28 ft. from floor to eaves.

The paper describes the arrangement of the structural members which were designed in accordance with CP 114, the code of practice for design of permanent reinforced concrete structures. A further limitation was that the largest single unit which could be factory produced and sent by road could not, in normal practice, exceed 40 ft. in length.

The author outlines how this was achieved using three pin portal frames, without scarfed or bolted joints, steel gusset plates, or other such forms of connexion.

The building was completed in less than one year, and at no time were more than sixty men employed on the site.

STRESS ANALYSIS OF RING STRUCTURES

The complex problem presented in the design of ring structures, resulting from the action of loads outside the plane of the ring, is illustrated in this paper.

The first part of the paper considers the analysis by strain energy methods of a ring mounted on a number of columns, such as arises in practice in a tank base mounting for a concrete tower. The author shows the cumbersome nature of the expressions which result, even after the customary simplification of the problem.

The second part of the paper outlines how this formidable problem may be solved by model analysis based on Muller-Breslau's theorem, which may be written "the deflected shape of a structure occasioned by unit distortion is the influence line for itself". Thus a measurement made of the vertical deflection at a point P in the structure due to, say, a unit vertical distortion at a support, is numerically equal to the reaction at the support in the original ring when the unit load is at the point P. The equipment with which the work is carried out is described.

For the example analysed in the paper it consisted of:

(i) drawing board.
(ii) model made of mild steel wire to represent the ring.
(iii) steel brackets to represent the supports.
(iv) bracket with guides on it to give unit deformation at selected points.
(v) vertical micrometer travelling about a centrally mounted pin.

In the example chosen the author shows the calculated values to be in complete agreement with those arrived at experimentally. The final step of calculating shears and bending moments presents little difficulty when the values of the reactions are known.

Extracts from *Civil Engineering*, January, 1956.

A Conducting Paper Technique for the Construction of Flow Nets

The rigorous mathematical solution of the Laplace equations governing the two dimensional flow in an isotropic medium is only possible in the simplest cases. Even approximate solution produced by relaxation methods can be very laborious.

The paper discusses the method of solving the problem by the electrical analogy method, using a potential flow tank, it then goes on to describe a simplified arrangement using a conducting paper instead of the more elaborate tank.

Reasonable solutions are obtained using the following equipment:—

2-volt accumulator
potential divider
sensitive galvanometer
conducting paper (Teledeltos paper Type L)

The method of constructing flow nets for two types of problem are described, the simple flow net under a sheet pile dam; and the more complex one for a flow net in an earth dam.

The adaptation of the work to take into account flow in anisotropic soils, and variations in the resistance of the Teledeltos paper is described.

The paper concludes that the accuracy is within 1 to 2 per cent of that obtained using relaxation methods, with a saving in time of 12 hrs. on a problem that would normally take 15 hrs.

A useful list of addresses, where supplies of Teledeltos paper and conducting paint may be obtained, is given at the end of the paper.

The Refacing of Four Concrete Dams

The dams connected with the Trawsfyndd reservoir in Merionethshire, North Wales, were built during the years 1924–27. Percolation of water, particularly at construction joints and at certain contraction joints, led to the remedial work described in this paper being undertaken.

Some 11,635 sq. yds. of existing surface on the water face was cleaned by wire brushing, hacked with handpicks, and then washed by sand and water blast.

Steel fabric reinforcement 4 in. × 4 in. × 8 g. was fixed to the face by means of nails driven into rawplugs set in the concrete and bent over to grip the steel. Gunite premix of 112 lb. cement to 5 cu. ft. of sand was applied over the surface for an average thickness of $1\frac{1}{2}$ in. with a tolerance of $\frac{1}{4}$ in. either way.

The cracks were chased out to a V shape, and after cleaning were filled in with a mastic bitumen over a coat of primer. Provision was made to allow for the Gunite facing to crack over the original cracks by cutting the reinforcing fabric on these lines.

The paper gives the organization required to carry out the work and describes the difficulties encountered. The paper is to be concluded.

THE MILITARY ENGINEER

(Journal of the Society of American Military Engineers)

November–December, 1955

"Nike Deployment", by Steven Malevich, Colonel, Corps of Engineers.

In an interesting and well illustrated article the author describes the development of the Nike weapon from its conception in 1945, through its firing trials, modifications, and acceptance to its production, installation and manning at numerous sites throughout the United States as the first guided missile system to be adopted for the defence of American cities in the event of aerial attack.

Nike, named after the Goddess of Victory, is a two-stage rocket. The first stage is a solid propellant booster which becomes detached in flight. The second stage or missile proper, has a liquid-fuelled rocket motor, guidance mechanism, and a war head. It is about twenty feet long, a foot in diameter, and weighs over half a ton. Its speed, range, deadlines, and other performance characteristics are classified information, but it may be said that this supersonic missile can, within its range, intercept any known type of fighter or bomber aircraft and even in fog, clouds, or darkness, close in and kill its target.

The Control Area—about seven acres—houses the ground control guidance equipment which includes three radars and a computor. The first, a search radar, detects the approaching aircraft. The second, a tracking radar, picks it up and feeds location and movement data into the computor. The third, a missile tracking radar, follows the missile and reports its movements to the computor. The computor calculates continuously the point of intercept between the missile and target and directs the missile towards the target.

A Launcher Area is located one to four miles away from the control area, requires about forty acres of land and houses six underground storage magazines per battery, launchers, missile assembly facilities, fuelling area, control van, generators, administration and housing facilities. Accommodation for the battery personnel of six officers and 103 other ranks is provided at the Launcher or Control Area or divided between both.

A Nike battery is ready for action twenty-four hours a day, and within a few seconds of the search radar picking up a target the guided missiles have been elevated above ground to firing positions on their launchers.

The article deals in some detail with the problems of site acquisition and on site building effort, production of weapons and equipment by a large and complex service-industry team using main contractors and hundreds of sub-contractors and materials suppliers, including, to increase output, the conversion of one Army Depot to a Nike missile manufacturing plant under the supervision of the Corps of Engineers.

January–February, 1956

"A Great New Scientific Beachhead", by Elliott B. Roberts, Captain, Coast and Geodetic Survey.

The author calls attention to an event of singular scientific importance: the Third International Geophysical Year due to occur during the last half of 1957 and throughout 1958.

The International Geophysical Year is a world-wide programme of co-ordinated observations in the earth sciences organized by the International Council of Scientific Unions. More than forty nations have now sent representatives to a series of meetings to co-ordinate programmes.

There have been previously two such internationally co-ordinated programmes of observation. The first was the International Polar Year held in 1882–83, and the other the Second International Polar Year of 1932–33. It is now realized that polar manifestations are but localized effects in a set of world-wide phenomenon and that since the work will take geophysicists of the world to equatorial and other parts of the world, as well as to little-known Antarctica, it will be a "geophysical" instead of "polar" year.

Based on the experience of the previous polar years, the author considers it safe to expect results of great theoretical and practical value, and does not consider this an extravagant hope, for even the single geophysical accomplishments of the past, such as the discovery of the ionosphere, or Kenelley-Heaviside Layer, have revolutionized our methods of communication, transport, conduct of war, and, in fact, of our entire mode of life. Complete knowledge of our physical environment and the fullest exploitation and use of it have become imperative requirements of human existence on earth.

In the Antarctic phases of the programme the United States National Committee have been fortunate in securing the large scale support of the Navy and Air Force and under operation "Deepfreeze", seven ships, an air squadron, and a special mobile construction battalion comprise the task force now operating in the Antarctic region.

In the outer fringes of the atmosphere it is intended to obtain physical observations by use of what is officially known as the L.P.R. (Long-playing Rocket), but also more popularly termed the earth-girdling artificial satellite. It is now possible to launch missiles capable of reporting observations by radio while circling the earth at speeds sufficient to complete the circuit in 1½ hrs., and to continue for weeks, before they fall to the lower atmosphere and end their life by burning like meteorites.

ENGINEERING JOURNAL OF CANADA

Notes from *The Engineering Journal of Canada*, December, 1955

The Helicopter and the Engineer

The military value of the helicopter, especially in undeveloped country, for reconnaissance, evacuation of casualties and the transport of senior officers has been amply demonstrated. Its commercial applications are not so widely appreciated, and this paper contains many ideas, backed by practical examples of their application in Canada, which are particularly interesting to the military engineer.

The author considers that, in commercial use, the aircraft and the helicopter are largely complementary, forming an ideal transportation team for work in remote areas.

The value of helicopters for the location of roads, pipelines and power cables has already been proved, and they can save considerable time and effort in topographical and geological survey work: aerial survey becomes both rapid and reliable if helicopters are used for triangulation to establish ground control. An important factor is the ease of co-operation between the various survey and reconnaissance parties, as all personnel can work from the same base.

Forest fire fighting, ice reconnaissance and routine patrol and inspection work are briefly discussed, but the main engineering application is perhaps the rapid transport of vital materials and plant, which can be slung externally if necessary. The author foreshadows the development of huge "helicopter cranes" to transport prefabricated structures direct to the erection site.

Atomic Power Development

Although Canada still has undeveloped water power and her own sources of oil, natural gas and coal, the eventual need for atomic power is clearly realized. This issue of *The Engineering Journal* contains two papers describing current progress in practical development. The basic work of the physicist is largely completed: the chemist and the engineer now face the task of practical and economic design. The first paper discusses the chemical factors involved: the second deals with the preliminary design for a demonstration nuclear-electric power plant in Ontario, known as N.P.D. The main problem is economic: both papers include interesting postulates.

Niagara Hydraulic Models

The use of models for the design of particular hydraulic structures in connexion with remedial works and development at Niagara has already been the subject of Technical Notes in the *R.E. Journal* (September, 1955 and March, 1956). The present paper contains a more general outline of the comprehensive series of model tests carried out, summarizes the major problems and their solutions, and sets out the economic and technical advantages of model analysis.

Notes from *The Engineering Journal of Canada*, January, 1956

Boilers and their Auxiliaries

Boilers fired by solid, gaseous or liquid fuels are still widely used for industrial purposes and for heating. This concise summary of the characteristics, of various types is unbiassed and eminently readable, and it includes valuable notes on the selection of fuel and firing equipment and on other auxiliary equipment.

Photoelasticity for Design Improvement

The photoelastic method of stress analysis is not a simple substitute for mathematical calculation in structural design. In the hands of the trained engineer it is however a most useful adjunct in cases where complicated conditions make the application of recognized formulae difficult. The scope and application of photoelastic techniques are outlined in an exceptionally well illustrated paper, which makes clear the necessity of special knowledge and training for competent interpretation. Though technique has greatly improved in the last thirty years, the method still appears to be of more value for comparative or research purposes than for quantitative calculation.

Notes from *The Engineering Journal of Canada*, February, 1956

The Design of Compressed Beams

Conventional elastic design applies a safety factor on stress to prevent yielding but, since structural steel is ductile and can deform without fracture or loss of strength, plastic theory, which applies a safety factor on load to prevent collapse, gives a more accurate estimate of conditions which will lead to failure. The plastic theory has been satisfactorily developed for the analysis and design of flexural members, but the design of compression members by this method is not yet fully understood. This paper includes a theoretical analysis of the effects of axial compressive forces on flexural members, and it is of particular interest because, in steel structures, most members are subjected to some combination of flexure, axial load and shear. The author presents a method of solution which is applicable either to plastic design or to conventional elastic design, and which is supported by a short series of practical tests. The more complicated mathematical work is in a short appendix, and the text is well arranged and clearly expressed.