The Royal Engineers Journal.

VOL. LVII. JUNE, 1943.

CHATHAM:
THE INSTITUTION OF ROYAL ENGINEERS.
TELEPHONE: CHATHAM 2669.
AGENTS AND PRINTERS: W. & J. MACKAY AND CO., LTD.

LONDON:
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THE INSTITUTION OF ROYAL ENGINEERS.

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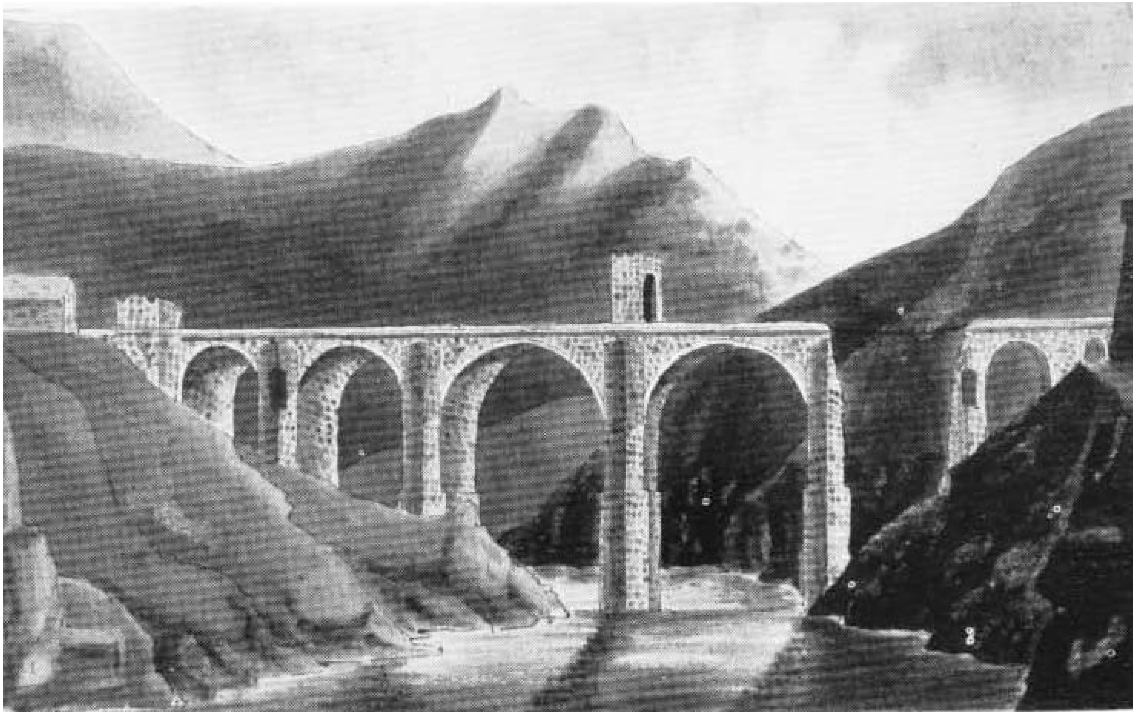


The Royal Staff Corps, 1800-1837. Trajan's Bridge at Alcantara

THE ROYAL STAFF CORPS, 1800-1837.

By LIEUT.-COLONEL F. S. GARWOOD, R.E. (Retired).

AT the end of the eighteenth century H.R.H. the Duke of York was enraged with the Board of Ordnance. He required small companies of Field Engineers to accompany an expedition to be landed on the coasts of Europe. These the Master-General of Ordnance had never heard of and could not supply; indeed he could offer scientific officers of Royal Engineers to besiege Namur, or any other fortress by the recognized rules of war or to protect our own coasts with brickwork bastions. But Field Engineers the Duke would have, and they should not be under the orders of any Department. His Royal Highness determined to establish a corps competent to discharge the duties usually devolving upon the Royal Engineers, which should be absolutely at the disposal of the Horse Guards; and so the Royal Staff Corps was born a hundred years before its time.

The duties of the Royal Staff Corps cannot be more clearly defined than by quoting a Circular Letter, signed by H.R.H. the Duke of York, as Commander-in-Chief, addressed to all officers under whom officers of the Royal Staff Corps may be employed.

"Horse Guards,
"28 Nov., 1808.

"Sir,

"It having been represented to me that some doubts had arisen respecting the relative situation of the officers of the Royal Staff Corps, when compared with that of the assistants and deputy assistants in the Department of the Quarter-Master-General, I have to acquaint you that as the Royal Staff Corps is by its Establishment attached to the Department of the Quarter-Master-General and placed specially under superintendence of that Officer, His Majesty considers that all the officers of that Corps, are for every purpose of service actually Assistants in the Quarter-Master-General's Department. The field officers of the Corps ranking as Assistants and the Captains and Subalterns as Deputy Assistants according to the Dates of their respective Commissions, and are entitled to the same Field Allowances and which you will be pleased to make known to the parties concerned accordingly.

"I have also to acquaint you that the principal purpose for which this Corps was established was to enable the Quarter-Master-General to give the most effectual assistance towards the Construction of Field works, Bridges, Roads, and the superintendence of all Labour comprised under the term Field Engineering. And as every possible care has been taken to introduce proper and capable persons into this Corps, both officers and men, for the performance of these duties, it is desirable that they should be directed to these important purposes, and not unless under circumstance the most urgent, be diverted to Services, not perhaps less useful, but which may as well be performed in the current routine of duty by the usual parties of fatigue.

"(*Signed*) FREDERIC, *Commander-in-Chief*."

The pick of the brains of the British Army at that time were concentrated at Woolwich. The Royal Artillery considered themselves the most scientific corps in Europe, it was their brains that produced the Shrapnel Case Shot and the Congreve Rocket. It was the R.A. who made the R.E. a brainy Corps, for by the end of the century 70 R.A. officers had transferred to the R.E. Among them is the name of C. W. Pasley, the originator of the S.M.E. It was from Woolwich that some of the best senior officers of the Royal Staff Corps came. And if Wellington's victories in Spain were often due to good staff work, it was thanks to the Duke of York whose foresight had provided him with officers carefully trained at a small Staff College.

The Staff Corps Companies were small units, a Major or Captain and three subalterns and less than 50 artificers, but if H.M. King William IV had not in 1830 presented the R.A. and R.E. with the motto "Ubique" like the Pioneer Companies who preceded the Corps of Indian Sappers and Miners, these small companies would have collected many Battle Honours. In the Spanish Peninsula they were first in the field and in 1808 there were 45 of the R.S.C. with Major-General Spencer's Corps on the South coast of Spain, and 50 with Sir John Moore in England about to sail.

In the period of enforced economy and retrenchment which followed after Waterloo the Royal Staff Corps became a luxury which the British nation could not afford and in 1830 all its officers were placed on half pay or replaced by R.E. officers, and subsequently all its rank and file were transferred to Companies of the Royal Engineers.

When, more than fifty years later, General Whitworth Porter published his *History of the Royal Engineers*, he had not one word to say about the existence and exploits of the Royal Staff Corps, and yet it is evident that their Companies were the direct ancestors of the R.E. Field Companies. The probability is that he had never heard of the Royal Staff Corps; yet the British Army, with its genius for improvisation in the actual course of hostilities, had once more invented a unit, which in later times was to become indispensable in every army.

But in 1815, when Paris was occupied by the British, Prussians and Austrians, the latter were incapable of finding any soldier capable of carrying out a simple job of work necessitating the use of blocks and tackle. Everybody who has visited Venice is familiar with the four bronze horses, made in 350 B.C. by the Greek sculptor Lysippus, which are the most precious possession of St. Mark. In 1797 they had been removed by the French and the Emperor Napoleon had harnessed them to a chariot, which he had placed on top of his Arc de Triomphe. The new King of France had graciously given them to the Austrians to be returned to Venice. The horses were lowered from their lofty positions by Major Tod's Company of the Royal Staff Corps.

The following are extracts from a diary, which Captain Thomas Scott of the Royal Artillery kept during the Occupation of Paris.

"*Thursday, 28th September*, 1815.—A disturbance took place owing to the attempt to remove the Venetian Horses from the Triumphal Arch, and our Artificers, lent to the Austrians, were driven away by the bayonet."

"*Saturday, 30th September*, 1815.—Rows said to be in Paris, owing to taking away of the four Venetian Horses. British regiment ordered out to keep tranquility."

The young officer who superintended the removal of the Venetian Horses was Tom Scott's first cousin, Lieut. Charles Rochfort Scott of the Royal Staff Corps. He was born in 1797 and was only 16 when he joined the Headquarters of the Royal Staff Corps as an Ensign on February 8th, 1813. He had spent two years as a Cadet at the Royal Military College, which on 1st October, 1812, had been moved from Great Marlow to Sandhurst. After he had spent a year at Hythe he commenced filling a notebook with the subjects in which a young officer of the Royal Staff Corps was instructed. He was a neat writer and an excellent draughtsman. This small book contains detailed descriptions of every expedient used in crossing rivers employed by military engineers in the operations in the Spanish Peninsula; it was compiled while the war was still in progress.

The Headquarters of the Royal Staff Corps were at Hythe; they lived in Barracks behind the Military Canal, in whose construction they had probably taken part. Hundreds of officers of the British Army have lived in their Mess when attending courses at the School of Musketry, in the days when the rifle was still the queen of weapons. *Sic transit gloria mundi*. Not one of us knew that the Royal Staff Corps ever existed. Who has ever heard of Wellington's Master Builder of Military bridges—Lieut.-Colonel H. Sturgeon, of the Royal Staff Corps ? After serving seven years in the R.A. he was promoted in 1803 in the Staff Corps and was killed in action in France, 19th March, 1814, while serving as Lieut.-Colonel on Lord Wellington's personal staff.

It is an indisputable fact that the Royal Staff Corps were responsible for the building of military bridges. Ensign Scott's notebook contains some admirable examples of their skill. When Ensign Scott was placed on half pay, he turned author, and as Captain C. Rochfort Scott, late of the Royal Staff Corps, he collaborated with Major Basil Jackson and wrote a very readable *Life of Wellington* for those who fought shy of reading Napier and Gurwood's *Dispatches*. As a preface to the description of each bridge quoted in the *Notebook*, I shall quote the remarks made in the *Life of Wellington* referring to the circumstances in which it was built.

BRIDGE ACROSS THE TIETAR, 1809.

(*Life of Wellington*.)—"Anxious to secure his junction with the Spanish Army, Sir Arthur Wellesley marched from Placencia on the 17th July, having determined to cross the Tietar River at the Venta de Bagazano, and move on

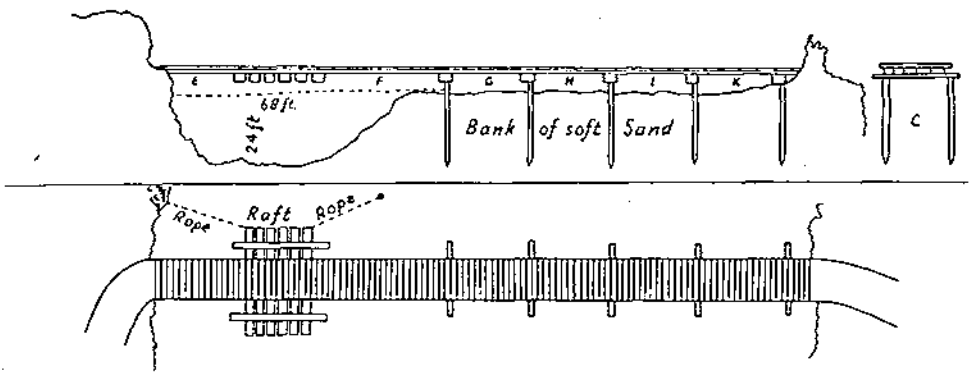


Fig. 1.

Oropesa. For the passage of the Tietar two companies of the Royal Staff Corps under Captain Tod, an able officer, constructed a bridge in a very ingenious manner, with materials obtained by pulling down an old house, and felling some fine trees in a wood three miles distant. 'Uniting intelligence with labour, he contrived without other aid than a few hatchets and saws, in one day to throw a solid bridge over the Tietar' (*Napier*) and no delay was occasioned to the army, whereas Victor had wasted many days in dragging up fifteen pontoons from the Tagus, to form a bridge at the same place. The troops passed the Tietar on the 18th and arrived on the 20th at Oropesa, where the desired junction with Cuesta's army was effected."

(*Notebook*.)—On the 16th July, 1809, Sir A. Wellesley ordered the two Companies from Placencia to the River Tietar to make a bridge to cross the Infantry of his Army on the 18th. The Profile of the River was found as on the other side (Fig. 1). The only material at hand was the timber of a large Inn at about half a mile from the place. Early on the morning of the 17th this building was unroofed and the Timber as follows was produced : 6 beams of dry fir, each about 20 ft. long and 2 ft. square, and from three to four hundred rafters about 10 ft. long and 4 by 6 inches scantling, 6 large doors and 200 running feet of manger.

Of the six large beams a raft was made by boring holes through the centre of each towards the end and passing a rope through them. This raft was placed in the deepest part of the stream, with the bored ends of the beams up the river. One end of this rope was made fast to a tree on the river side, and the other to a stake driven fast into the sand on the shoal of the other side.

A party of 500 men with saws and axes was sent to a distance of 3 miles under Lieut. Westmacott to procure young pines to make the stakes and caps C, and the bearers E.F.G.H.I.K.L. in number 20, each from 25 to 30 ft. long and from 6 to 10 inches diameter, with ribbons to keep down the plank of the same kind of pieces split thus (horizontally) and tied on each of the trestle heads. The Rafters, Doors and Mangers were found sufficient for planking, but as they were too thick for the nails we had it was necessary to secure them on the bearers by the ribbons as above, laid all along the cut ends and tied with willow twigs to the caps of the stakes. A stool was made for the men who drove the stakes, to stand on while so employed. Large wooden mallets made on the spot were used for that purpose.

The bridge was only for immediate use and not to be kept up after the troops passed. Lieut. Stavely was left in charge of it until all had passed.

THE LINES OF TORRES VEDRAS, 1809.

(*Life of Wellington.*)—"Determined by the above considerations, Lord Wellington made choice of a position extending from Alhandra, on the Tagus, across to Torres Vedras and the ocean. The whole of this ground is strong by nature; but a minute examination of every part of it satisfied him that art could render it nearly impregnable, if properly defended. He therefore drew up for Lieutenant-Colonel Fletcher, his commanding engineer, a memorandum, dated the 20th of October; in which after specifying all his general views for defending Lisbon, he minutely enters into the subject of fortifying the lines of Torres Vedras, points out the best situations for forts and redoubts, and for the formation of entrenchments, inundations and the creation of such obstacles to the attack of an enemy as the nature of the ground would admit of; his object, in the first instance, being to ascertain the amount of labour and length of time required for the stupendous works contemplated, including roads of communication between the several parts of the position."

It is to be noted that the Chief Engineer was not asked to make plans for the defence of Lisbon, but was given a cut-and-dried scheme, which had already been prepared by the Commander-in-Chief and the officers of his staff. Wellington was certainly extremely fortunate with his Quarter-Master-General, and Scott's *Notebook* commences with 27 pages of instructions for the guidance of staff officers, issued at Cadiz on 15th July, 1810, and signed George Murray, Qr.-Mr. General. Every officer of the Royal Staff Corps was *ipso facto* a member of the Q.M.G.'s Staff and especially trained to make plans and sketches and to be a specialist in Field Engineering. The lines at Torres Vedras were in course of construction and the Quarter-Master-General seems to have forgotten no single item which was necessary to make them a success. The document is too long to quote here in full, but it commences: "One of the first duties of the officers of the Quarter-Master-General's Department is to acquire a knowledge of the Country which is the theatre of operations of the Army." Staff officers are told that sketches of positions should never be made upon a smaller scale than four inches to a mile. The Memorandum concludes with a specimen of a road report from Truxillo to Merida. Torres Vedras must have entailed many sketching expeditions on the officers of the Royal Staff Corps, but any modern General Staff Officer would have been a proud man had he produced as good a road report as this.

General Porter has claimed all the credit for the Lines of Torres Vedras for the Royal Engineers, but admits that never more than eleven officers were employed on them at one time and that 18 of the Royal Military Artificers held positions of responsibility. The fame of Torres Vedras was spread to the ends of the earth, but its meaning was unrecognized, which was that Lord Wellington was the first modern general who collected around him an adequate and well trained staff. He picked up good men wherever he could find them and attached them to his person. Sir Colin Campbell was present at every one of his battles; he had come to his notice at Ahmednugger: "General Wellesley, who was a close spectator of the attack, noticed a young officer of the 78th who having with great gallantry led his men to the attack, was thrust from the top of the wall by the enemy, and fell, as the general supposed, severely wounded, if not killed by the tumble. In a moment, however, he was again on his legs and seen mounting to the assault, having sustained but slight injury from his fall. Next morning he was sent for by the general, who offered him a situation on his staff." With his efficient staff Sir Arthur Wellesley could travel about Spain as he did, confident that his many schemes would not get a chill in the incubator during his absence.

Flying Bridge on the Tagus, 1810.

(*Life of Wellington.*)—"In this disposition, the strength of the combined army was in the centre, while militia and ordenanca formed the wings; and by the admirable arrangements of Lord Wellington, upwards of 30,000 of his

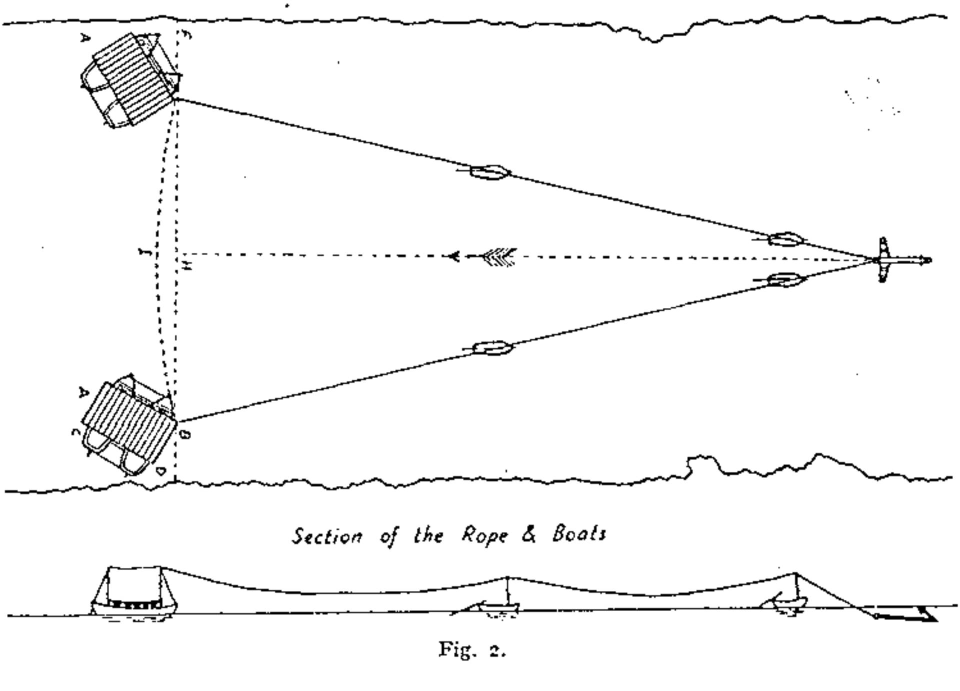


Fig. 2.

best troops could be assembled in two marches upon any point menaced by the enemy. In order to facilitate the operations of his right wing under General Hill, a bridge of boats was thrown across the Tagus at Abrantes, and another over the Zezere: an excellent road was also formed from Abrantes by the left bank of the Tagus to Villa Velha, where a flying bridge communicated with a good road leading to Castel Branco."

(*Notebook.*)—A Flying bridge was laid on the Tagus at Villa Velha by Lieut. Westmacott on two country boats. A strong rope was stretched across the River to pass this bridge by. 12 Seamen were constantly on duty to pull it backwards and forwards; a rope with a large hoop running on that stretched across, was kept constantly fixed to this bridge lest the force of the stream should force the men to let go the rope in hauling across. A scaffold was fixed on each side for the carriages and horses to go off and on the bridge; a good rail was placed all round to prevent the bullocks from jumping off it. In laying this, as well as all other floating bridges, the balks or bearers should cross entirely over one boat and rest on the gunwale of the other.

An entire Bridge of country boats was laid over this place afterwards; as was another at Abrantes and also one across the Zezare at Punh, etc. At Villa Velha I think 25 boats were used and at Abrantes, where the river was wider 57 were used.

Pontoons, such as are used in the British Service, are only useful where the water is smooth and the stream not above three miles per hour. One of these on the Guadiana near Badajos sank during the siege of that place and occasioned a great deal of inconvenience; another was placed by Lieut. Piper, Rl. Engineers, on the Tagus at Almaraz to pass the Army of Genl. Hill at the time of the siege of Burgos; it was constantly obliged to be removed on the least increase of the river and could not be replaced until the water subsided. If these tin pontoons were made in the shape of boats instead of square boxes they might be as easily carried and would be infinitely more useful.

During the retreat of Marshal Massena from Portugal he destroyed several stone bridges, first at Pirnes; this was of two arches, about 20 ft. wide. It was repaired by pulling down an oil mill, which stood near, for bearers and taking the doors of houses and sides of Indian corn chests (which in Portugal are very large) as planking; no tools or nails were used as neither could be procured. The second was at Fez do Aroue; the arch destroyed here was 70 ft. wide and no timber of sufficient length could be got. A stool bridge was made during the night, some distance up the river. (*Note.*—This last was the trestle bridge over the Ceira referred to below.)

The Bridge at Ponte Murcella, 1811.

(*Life of Wellington.*)—" During the night of the 16th (March) a trestle bridge was thrown over the Ceira by the Royal Staff Corps and the army crossed in pursuit of the enemy on the following morning. Massena was found to have placed his army in position behind the Alva and on the Serra de Moita; and hoping to maintain himself for some days, had sent out his foragers to procure supplies. But his opponent too well knew the advantage of pressing a retreating enemy to allow him any respite; and the bridges of Murcella and Pombeira having been destroyed he directed one to be forthwith constructed. ' The Alva was deep, wide and rapid; yet the Staff Corps succeeded in forming a most ingenious raft bridge, and the light division immediately passed between Ponte Murcella and Pombeira, and at the same time the right wing of the army entered Arganil, while Trant and Wilson closed on the other side of the Mondego.' " (*Napier*).

(*Notebook.*)—The third was Puente Murcella. Timber of a sufficient length could not be got there and a bridge was made, as follows, at some distance above. The stream was too rapid and the water too deep to admit of anything being fixed in the river. The left bank was rocky and nearly level with the water; the right was bounded by a stone wall or wharf about 5 ft. higher than the water.

A working party of 200 men was immediately sent into the village to collect all kinds of dry timber to make a raft. A sufficient quantity being collected it was formed on the Bank at A. While the timber was collecting two Ring bolts were let into the rocks at D and C and six pine trees of about 60 ft. long were felled and brought to the spot by the marauders, who accompanied the Army and who were seized on and compelled to perform the service. The Raft being ready one of these trees was laid on it and well secured by spikes and cords; a hole was bored in the other end of the tree and it was secured by a heel rope to the ring bolt at D. Bearers were laid under the raft, while it was constructing, to launch it, which was done and a strong party held on the rope EF easing it down the stream to G, the place proposed for the bridge. The rope was then secured to the ring bolt at C, and two additional turns were taken round the tree and through the bolt to secure it against the force of the current. A firm footing being thus secured in the middle of the river, a second tree was prepared by boring a hole in its end ; it was then slipped along the first beam and secured by a heel rope to it at G. A large cask was procured from the village and well lashed under the other end of it ; the tree and cask were then launched into the stream and shoved out by poles and boathooks from I to K when being caught by the stream, it was gently and carefully eased down by the rope LM

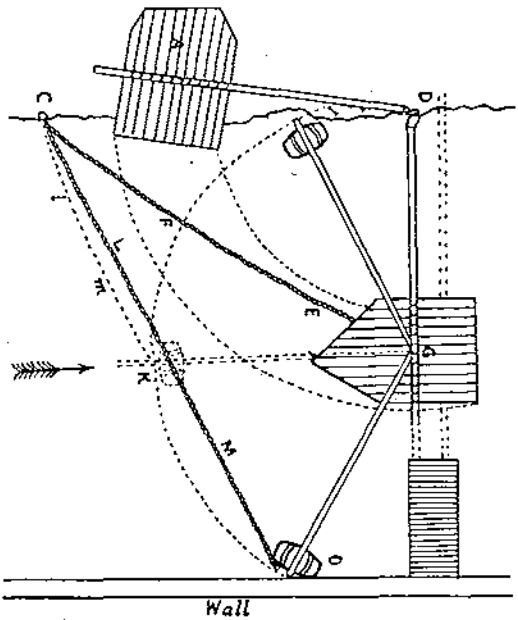


Fig. 3.

to the situation O against the wall. About 30 men were then sent along across this tree and by the help of a small tackle, fixt to a post on the wharf, hoisted up the Cask and end of the tree on the wall.

Two other trees were immediately laid parallel to the others and the whole planked over with doors, chests and such other articles as had been collected during the time the work was going on.

Bridge of Almeida.

(*Notebook.*)—The last bridge the French destroyed on their retreat from Portugal was the stone bridge across the Coa at Almeida.

This bridge was ordered to be repaired as a Permanent Communication and of course more time and labour was expended on it than on any of the former. As soon as the plan was determined on the Notches were made in the masonry by men lowered down on a scaffold for that purpose. Two frames were then made. When completed the cills were laid on the notches A B and the frames put together in an upright position as represented by the dotted lines AF BE. Tackles were then applied to both sides of each frame at the extremities E and F. The other end of the tackles being fixed to the bolts let into the masonry about 30 feet back of the fracture. 50 men were then put on each of the tackle falls and the frames were lowered down to H. Gangboards I K were then shoved out and men sent out on them to put in key bolts which were previously prepared. A ridge pole was then laid on from which to the sides the timber we had was sufficient to reach. The braces 1, 2, 3 were afterwards put on to secure it.

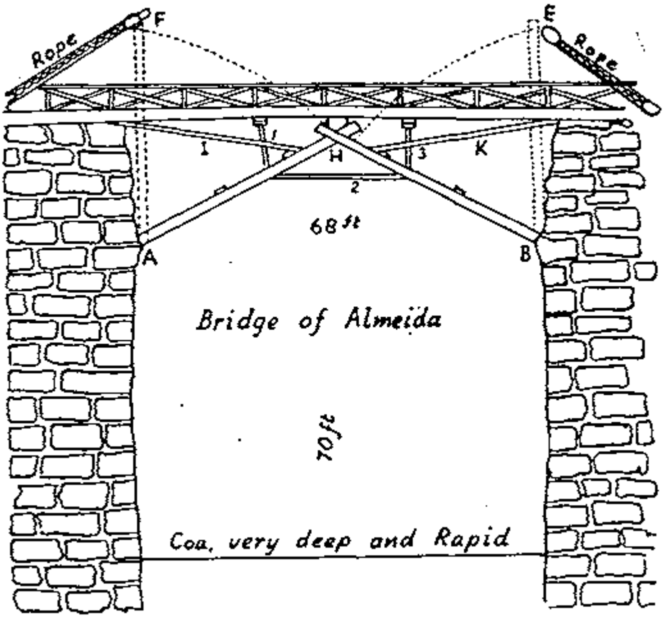


Fig. 4.

THE BATTLE OF FUENTES DE HONOR—3RD MAY, 1811.

(*Life of Wellington.*)—" Lord Wellington expected a renewal of the attack on the morrow; and although he felt little doubt respecting the issue of the contest, no precaution was neglected to strengthen the position of his army and secure its retreat, should a retrograde movement become necessary. His line, which extended across the table-land between the Turones and Dos Casas, was intrenched during the night; and Captain Tod, with two companies of the Royal Staff Corps, was despatched to throw temporary bridges over the Coa below Almeida. The point selected for this purpose was near the broken bridge of Pinhel; and by extraordinary exertion that able officer constructed two rough but ingenious bridges with such materials as could be collected in the adjacent villages, which were ready by mid-day on the 6th."

A TEMPORARY BRIDGE ON THE COA.

(*Notebook.*)—Early on the morning of the 3rd day of the Battle of Fuentes de Honor, the two Companies of the Rl. Staff Corps, then with the Army, were sent to the neighbourhood of the Puente de Pinhel on the Coa, which had been destroyed by the enemy in their retreat from Portugal, to make as many communications as possible across the river, in order to pass what portion of the Army might be thought necessary, in the event of its being unable to continue to cover the blockade of Almeida.

On their arrival at the spot it was found impracticable to repair the stone bridge, from the shattered state of the remaining part of the piers, and almost total want of materials within any reasonable distance. Six poplars and some large elms that grew on the bank about two miles upwards, were all that could be procured. These were immediately felled and with very great difficulty floated down the river to two places that had been fixed on, to attempt making temporary bridges. Both these places were where the river narrowed, forming rapids so deep and strong that no hold could be got of the bottom. Each of these places was from 60 to 70 feet wide, but as both Bridges were made similar, I shall only describe one.

The farthest side of the river could not be got at by any means in our power, it being then a considerable flood. The profile of the bank next us was the line from A to B (Fig. 5) in solid granite rock. It was immediately altered to C D by

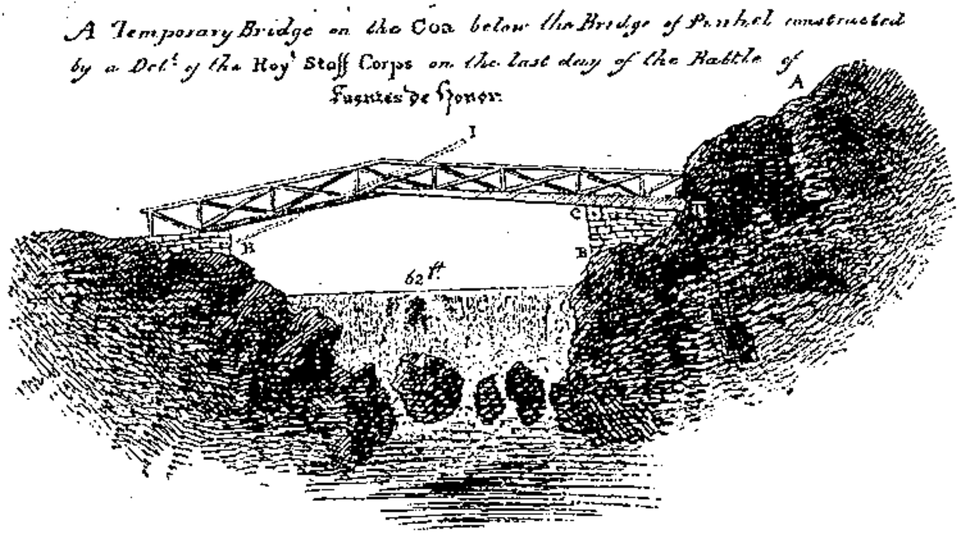


Fig. 5.

cutting a notch at D about 8 feet long horizontally, one foot high, and about the same depth and raising the space to C with dry masonry, coped by a beam of Timber on the extreme edge. Meanwhile a road was made along the face of the rock.

Two trees were then placed sideways with their large ends inserted in the notch above-mentioned and by the help of levers and iron bars were levered into position overhanging the stream. The ends still continuing to be secured in the notch. Handspikes were then lashed on these trees at certain distances to enable men to go out on their extremities and push across to the opposite bank two light poles, represented by the dotted lines H I (Fig. 5), across which poles some men were sent and having thus reached the opposite bank, the rest of the work was soon completed.

The Capture of Ciudad Rodrigo, 1812.

(*Life of Wellington.*)—" Ciudad Rodrigo stands upon an eminence that rises abruptly from an extensive plain on the right bank of the Agueda, which river is encased by rugged banks, and though at times fordable in many places, at others is liable to rise rapidly to the height of many feet, producing a rush of water that no temporary bridge can withstand. From these peculiarities in its character, this stream constitutes the strength of the fortress and was, on the present occasion, the main obstacle to the siege. A trestle bridge of a peculiar construction and great strength was, however, projected by Major Sturgeon of the Royal Staff Corps, to overcome these difficulties and, being approved by Lord Wellington, the artificers of that corps speedily completed it; so that by the commencement of January all things were prepared for one of the boldest operations on record."

The *Notebook* contains a complete description of Sturgeon's trestle bridge, with detailed drawings. It says :—

"The next bridge of any importance that was constructed was that across the Agueda, near St. Felice el Chico, to enable Lord Wellington to attack Ciudad Rodrigo. It was placed about two miles below the town. In the winter of 1811 his lordship directed Col. Sturgeon to prepare in the Arsenal at Almeida a bridge of Chevalets to cross any of the neighbouring rivers. A sufficient quantity was prepared for a breadth of 500 ft. of such construction as to withstand the winter torrents that during floods or sudden thaws, which might then be expected, sometimes raise these rivers to a very great perpendicular height. They were to be got ready as soon as possible, viz. :—

30	Chevalets.
500	Feet running plank, each 14 ft. long.
160	Joists each 10 ft. long, 5 by 10 inches.
30	Piles and Piling machine on wheels to work in water.
120	Fathoms of strong chains.
3000	6-inch spikes.
6000	2-inch nails for the casing.
	Hawsers, tackles, etc., etc.

"His lordship ordered that every article should be transported with the utmost possible dispatch to the situation he had chosen as above and to be placed without a moment's delay."

BRIDGE ON THE AGUEDA—10 MILES BELOW CIUDAD RODRIGO.

"As soon as everything was got in its place, a row of piles was driven in the river about three fathoms above the bridge, one opposite each Chevalet, and a chain being passed round each pile was secured to the framework, so as to prevent the whole from floating away in the event of the river rising over the top of the bridge, which was 12 feet higher than the usual surface of the water. The day after the place was carried by assault this bridge was removed and Lieut. Dumaresq was charged with it at Almeida."

Justice must be done to Major-General Porter, after saying in big print that Lieut. Piper, R.E. had been placed in charge of an equipment containing twenty-four pontoons in order that a bridge may be formed at Abrantes, which was more than a hundred miles from Ciudad Rodrigo, he quotes from Burgoyne's *Journal*, December 30th : "A bridge of trestles has been thrown across the Agueda by the staff corps." The R.E. Historian *does* mention an officer of the Royal Staff Corps, when he describes how Ciudad Rodrigo fell :—

"On the afternoon of the 19th, Lord Wellington, having made a close reconnaisance of the ramparts, decided not to delay for any further advance, but to storm that night. For this purpose he sat himself on the reverse side of the trench and wrote in pencil his order for the operation. The attack was begun a few minutes before 7 o'clock by a column composed of the 5th and 94th Regiments, guided by Major Sturgeon of the Royal Staff Corps."

In the *Life of Wellington* it is stated that: "Lord Wellington on the report of Major Sturgeon, who had closely examined the place, decided on attempting to carry it by storm that night?" Everything tends to show that this officer, being a member of Lord Wellington's personal staff, was always at his elbow to offer him sound advice on all matters with which the officers of the Royal Staff Corps were supposed to deal.

I have styled him a Master Builder of Military Bridges; he was in fact a wizard, and there follow three examples of his use of rope mats, stretched as tight as possible with blocks and tackle, and capable of supporting the bridge load by suspension, doing away with timber baulks. Many of us in early life have played with single-lock, double-lock and frame bridges made with spars and rope. We attributed such contrivances to our R.E. predecessors of the Peninsular War, in which we were wrong. Their invention was due to the Royal Staff Corps and their good friends in the Royal Navy, who provided them with stores. And they knew more about spars and cordage than any man now living.

Here is the first problem which faced Colonel Sturgeon. It is a sketch of one of the most famous old Roman Bridges in the world, and the condition in which it unfortunately found itself in 1809.

TRAJAN'S BRIDGE AT ALCANTARA. (*See Frontispiece*)

Breadth of Arches—45 ft.—75 ft.—104 ft.—104 ft.—75 ft. (Demolished)—45 ft.

(*Notebook.*)—In April, 1812, Lieut.-Col. Sturgeon was sent from Punto Guinaldo to Badajos and Elvas to prepare a net of rope to cross the fracture in the Roman Bridge across the Tagus at Alcantara. The following materials being provided, viz.:—

4	Beams of Poplar, each		30 ft. long by 12 by 8 inches.
8	do.	do.	20 ft. do. by 6 in. square.
48	Joists each 12 ft. long		3 by 5 inches.
120	do.	do.	$1\frac{1}{2}$ by 5 inches.
100	Half inch screw bolts each 10 ft. long.		
100	inch and a half plank, each 12 ft. long, 1 ft. wide.		
50	Two inch plank for the ends same dimensions.		
10	Triple Blocks.	Sheaves 12 in. diam.	Brass cogged and iron pinned.
10	Double do.	do.	do.
10	Double do.	do.	6 in. diam. for working tackles and guy.
10	Single do.	do.	
450	fathoms $6\frac{1}{2}$	Rope for great mat and bridge bearers.	
200	fathoms $4\frac{1}{2}$	Rope for falls for bridge tackles.	
200	do. $2\frac{1}{2}$	for working tackles and guys.	
100	do. $4\frac{1}{2}$	for straps round the beams.	
1000	do. 3 and 4 yarn spunyarn.		
140	yds. strong tarred canvas.		
5	cwt. bar iron for cramps and bolts.		
200	lbs. Lead.		

A lot of miscellaneous stores.

Two Pontoon Carriages.

4 Crabs or small capstans.

30 Common Carriages.

6 Galera Carriages.

The Galera is a particular description of light car, drawn by 4 Mules and used in Spain for expeditious travelling. It has a cover of canvas to cover the people and goods travelling from the sun.

Construction.—The Pontoon House at Elvas being selected to make the Net work in. The two Beams A B were placed on stools 4 ft. high, at the distance of 90 feet asunder (breadth of gap to be bridged) and secured to the end and side walls of the house by braces and trestles (see Fig. 6), to prevent them approximating by the strain of the ropes.

The $6\frac{1}{2}$ in. rope was then stretched round them to an equal strain by the working tackles. 18 Lengths formed the Bridge, placed 1 foot asunder from centre to centre of the ropes. The eight pieces of six inch square being notched, and the notches being seared with the arm of an iron axletree made hot, to prevent their chafing the ropes, they were then laid on the net work, each notch receiving a rope at equal distances, and there lashed on with 4 yarn spunyarn, the Ropes being netted as on the sketch. The sleepers were then prepared in chains. (These chains were made of short baulks, set alternately single and double, the ends of the double ones being strung to the ends of the single ones, placed between them, thus making a continuous and flexible chain.) These chains of sleepers were laid longitudinally from end beam to end beam, the joints resting on the transverse beams 1, 2, 3, 4, 5, 6, 7, 8, and the ends were lashed to the great End Beams A B. The planks were prepared by jointing, cutting to a length and boring a half-inch hole in the end of each to pass a ratline to secure them to the sleepers and to each other.

The whole being ready to be packed up for transportation, the great net beams and transverse bearers were rolled up and put on one of the Pontoon Carriages and that and the whole apparatus were transported to Alcantara.

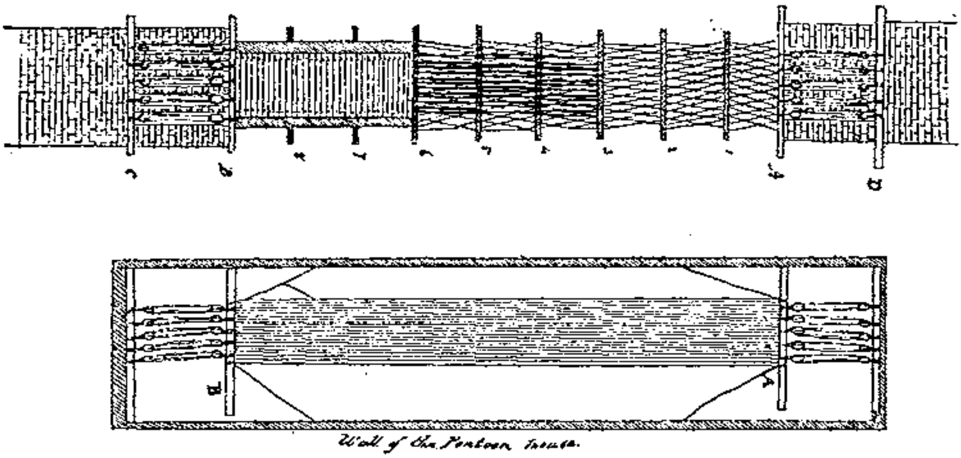


Fig. 6.

While these preparations were making at Elvas, Lieut. Perry was left at Alcantara to prepare the edges of the fractured part and to cut channels in the masonry to receive the purchases. The first process on the spot was to stretch four strong ropes from side to side, extending from the beams C to D as conductors to pass the great net over; this done the rest of the work was completed without difficulty as on the Sketch.

A similar Bridge was made in the new Museum at Madrid, and transported to Almaraz, where it was laid across the gap, 143 Feet wide, in the stone bridge across the Tagus there.

CHARLES FIFTH'S BRIDGE OF ALMARAZ.

Breadth of Arches—143 ft. and 110 ft. Height from water to top—122 ft.

This rope bridge proved perfectly successful as stated in *Life of Wellington*, 1812:—" Lord Wellington, while thus depriving the French of their communication across the Tagus, saw the importance, in aid of his projected movement, of establishing a permanent communication for the use of his own army across that river. Alcantara offered the most eligible point for this purpose, as the approach to it from the south was covered by Badajos; but an arch of the stupendous Roman Bridge, 90 feet in height which there spans the Tagus, had been destroyed in 1809, leaving a chasm 100 feet wide, which it had been reported impossible to repair; while the banks, lofty and precipitous, with the stream at times an impetuous torrent, rendered a boat bridge wholly unsuited to the object.

" Major Sturgeon of the Royal Staff Corps was sent to examine the broken arch, and his fertile invention suggested an application of cordage, which was prepared at Elvas, and on being stretched across was found fully adequate to the purpose; a small battering train being shortly after taken over without the least difficulty by Lieut.-Colonel Dickson of the Royal Artillery."

BRIDGE ACROSS THE ADOUR.

(The *Notebook's* account.)—On the 8th February the Marquis of Wellington determined on constructing a floating bridge across the Adour, below the fortress of Bayonne, with a Boom to protect it from any hulks or Fire vessels that the enemy might drift down the stream with a view to destroying. The bridge was to be at a place previously fixed and reconnoitred, at the distance by the river 2½ miles from the wooden bridge which connects the Town with the Citadel and is the same over which the great Chaussée to Madrid passes and 1½ miles from the confluence of the Adour with the sea.

The magnitude of the river, the strength of the current, it being the season

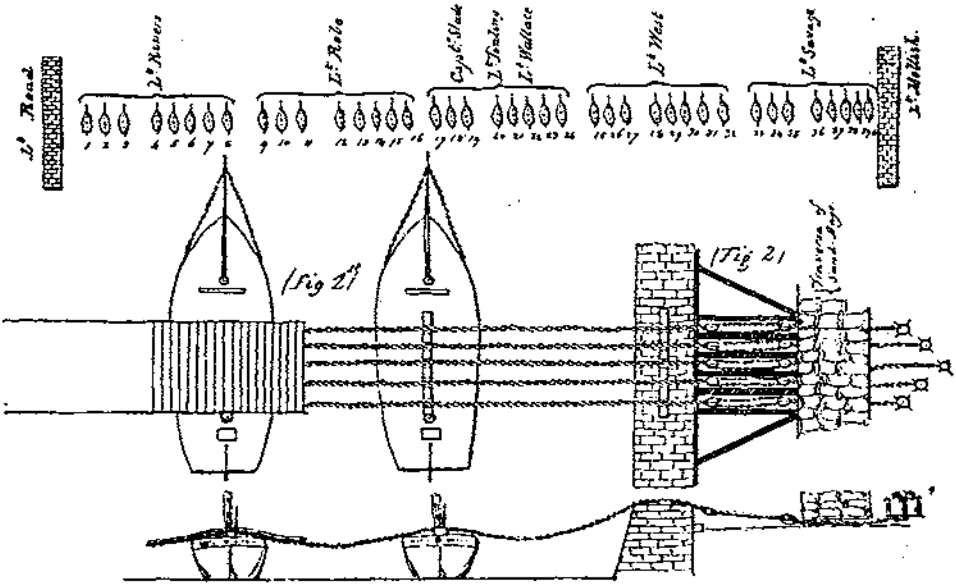


Fig. 7.

of the year when the mountain floods were expected, and the occasional effects of particular winds on the surface of the water, rendered it unsafe to trust to the copper pontoons attached to the army, even if a sufficient quantity could have been spared from other services. His Lordship therefore decided upon hiring *Chasse Marées*, a species of coasting vessel, used on the shores of the Bay of Biscay, of from 20 to 40 tons burthen, and measuring generally about 50 ft. in length on deck and from 12 to 15 on the beam. 48 of these vessels were immediately taken up in the ports of St. Jean de Luz, Socoa and Passages, and loaded each with 48 three-inch planks, each 12 ft. long and one foot wide. 2 hand saws, 2 axes and 2 skeins log line for lashing on the planks. One sleeper 10 inches square notched thus. (The figure shows this 12 ft. long transom with five grooves cut in it for ropes.)

Two men of the Corps of Sappers and Miners were put on board each, for the purpose of cutting away the waist boards level with the decks, the moment the vessels arrived in their stations in the Adour, in order that there might be no delay in stretching the cables, as soon after the vessels were moored in their place as possible. In consequence of the difficulty in procuring in any reasonable time in the vicinity of St. Jean de Luz, a sufficient quantity of balks to answer as bearers between the boats, His Lordship determined on the suggestion of Lieut.-Colonel Sturgeon to use 13-inch cables stretched tight by tackles and capstans and resting on the decks of the vessels, which were to be placed 40 ft. from centre to centre in a line across the river. These cables were to be 5 in number and placed at the distance of 2½ feet from each other, being secured equidistant by lashing in the notches of the aforesaid sleepers, one of which was placed fore and aft on the deck of each of the vessels.

Sixteen thirteen-inch cables were procured, some being taken by the Admiral from the Transports and some purchased at St. Jean de Luz. These were put on board those of the *Chasse Marées* that were intended to be placed in the centre of the bridge, and so coiled that they could be handed out to both sides of the river at the same time. The river was bounded on both sides by perpendicular stone walls 14 ft. high and the same thickness. That on the left bank was backed by sand, level to its surface; while the ground behind the wall on the right bank was 12 ft. lower than the top of the wall and covered at high tide by 7 feet of water. The rise of the tide at Springs was 14 ft. perpendicular. Cables were preferred to balks, because from their elasticity they were better calculated to meet the rise and fall of the water, as well as the motion of the surface and besides, in the event of the enemy's being able to force or break the Boom by his hulks, fire vessels or other means floated down the stream for that purpose, these five cables would have proved an additional obstacle and most likely would have arrested their progress until the Store and Provision ships, that were anchored below the bridge could, by cutting or slipping their cables be got out of the way.

It was determined that the ends of the cables should be secured on the right bank by affixing an eighteen-pounder iron gun and throwing them over the back of the wall into the mud, serving that part of the cables, which rested on the masonry with green bullock hides to prevent them chafing, and to tighten them on the left bank by capstans and gin tackles fixed to a frame of timber prepared on purpose, laid on the sand behind the wall, three feet lower down than the top of the masonry and loaded in the rear by a traverse of sandbags (see Plan No. 2, Fig. 7).

The *Chasse Marées* were told off into five divisions (see Fig. 7). The centre commanded by Captain Slade, assisted by Lieuts. Tinling and Wallace, the two left by Lieuts. Robe and Rivers, and the two right by Lieuts. West and Savage. Lieut. Read (Reid) was trusted with hoisting the guns over on the wall on the right bank and securing the ends of the cables to them; and Lieut. Mellish (Melhuish) was charged with securing and tightening the purchase on the left bank.*

Lieut.-Cols. Elphinstone and Ellicombe proceeded by land with Sir John Hope's column to determine the precise place where the bridge was to be placed, having in view to hide it as much as possible from the place, allowing at the same time sufficient room for the anchorage of from two to three hundred vessels between it and the river's mouth.

Boom.—A flexible Boom was prepared at the same time, under the direction and with the assistance of Admiral Penrose, for the protection of the bridge. It consisted of masts of from 50 to 100 feet long and from one to two feet in diameter, placing the stronger in the front line; these were anchored each individually by the centre, those in the first line being anchored up the river stream, and those in the rear line having their anchors down the stream to meet the tide of flood. The masts in the first line were placed 20 feet asunder and connected with chains as well with each other as with those in the rear line, making the masts in the one line cover the intervals in the other. These lines were to be 24 ft. asunder and the chains were to be allowed to hang slack so as to be about 12 ft. below the surface

* All these were Royal Engineers, except Wallace, who was a Sub-Lieutenant in the Royal Sappers and Miners.

of the water, this was calculated to give that elasticity so necessary to meet the violence of a first shock. Two strong 13-inch cables were at the same time stretched along the whole line of masts and set as tight as possible, securing them by lashings to both ends of each mast. Four gun-boats were placed in advance of this boom to assist in its protection, and on each bank of the river was placed a battery of three travelling eighteen-pounders, while light boats were constantly kept in readiness with graplings to meet and anchor anything that might be drifted down the stream before it reached the boom. During the night guard boats and boats of observation were kept constantly rowing about.

The Making of the Bridge.—On the evening of the 22nd the whole being ready, went to sea under convoy of the *Porcupine*, Frigate, Admiral Penrose's Flagship, the *Lyra*, Brig. of War, Capt. O'Reilly, and five gun-boats commanded by Capt. O'Reilly. The wind during the night was fresh but contrary, next day light and variable; on the 24th in the afternoon 34 of these vessels entered the Adour, one foundered on the bar, one and a Transport were driven on shore on the beach and 12 were forced back to St. Jean de Luz. Two transports carrying the boom entered at the same time and a sloop similarly employed was driven on shore on the beach. 4 of the 5 gun-boats also entered at the same time and the other was driven on shore and finally dashed to pieces.

This diminution of means (particularly the *Chasse Marée* No. 38 in which were the three officers, three of the cables and the Commissary of Provisions with his stores and also No. 26 with two cables) rendered a removal of cables and a different arrangement necessary, which added to the difficulty of mooring the vessels, except at slack tide, occupied the whole of the days of the 25th and 26th, on the evening of which last day it was completed.

Of the 34 vessels which entered 25 were put into the bridge—4 were held in reserve to replace any that might be destroyed by the enemy's fire vessels or other means of annoyance and five were given to the Commissariat to go to Passages for stores. After the suspension of hostilities the boom laid down above the bridge for its protection was taken up, and placed between the vessels as bearers; their lengths made it practicable to remove six vessels from the bridge, which six with the four in reserve were given over to the Ordnance and Commissariat for other services. On the 12th of May this bridge was broken up.

The R.E. Take All the Credit.—Nearly 100 pages of Whitworth Porter's *History of the Royal Engineers* are devoted to the Peninsular War, but bridging is scarcely mentioned until we come to the end of the last chapter, which describes the Passage of the Adour. The reader would suppose that the C.R.E., Lieutenant-Colonel Elphinstone, was entirely responsible for the design and execution of the work, which is described in a quotation from *Napier*:—" This work has been justly characterised by Sir W. Napier, in his description of the operation as a stupendous undertaking which must always rank amongst the prodigies of war. In fact the very audacity of the project became one of the elements of its success. It was deemed so impracticable that the French made no effort to guard against it. They were consequently unable to offer any effectual opposition whilst it was being carried out."

But the Bridge across the Adour itself bears irrefutable evidence as to who was its designer, for the roadway was suspended on exactly the same principle as the repaired arch of the Bridge at Alcantara. Whitworth Porter's description of the design and siting of the bridge several times makes use of the ambiguous phrase "it was decided." But the decisions were made by Wellington himself on the advice of Lieut.-Colonel Sturgeon, who was on his personal staff. And even Major Alexander Tod could give decisions, for every Staff Corps officer was a member of the Quartermaster General's Staff. This is what his quondum subaltern, Capt. C. R. Scott says in his *Life of Wellington*.

" The plan of the bridge over the Adour was proposed to Lord Wellington by Lieut.-Colonel Sturgeon of the Royal Staff Corps. The *Chasse Marées*, taken up for this service in the different Spanish ports were the vessels in which the coasting trade is carried on. They are two-masted decked vessels of from 20 to 40 tons burthen. Twenty-five of these vessels were anchored stem and stern, to resist the ebb and flow of the tide, at intervals of 30 feet; and five 12-inch cables were stretched across the river, resting on sleepers placed fore and aft and well secured to the decks of the vessels.

"The operation of laying the boom and bridge commenced immediately under the direction of Major Tod of the Royal Staff Corps, assisted by officers of the Royal Navy and Royal Engineers; but owing to the non-arrival of so many of the vessels laden with part of the bridging materials, and the difficulty experienced in mooring the vessels, which could only be done at slack tide, the bridge was not completed until the evening of the 20th February."

On the 19th March, 1814, Lieut.-Colonel Sturgeon was killed in a skirmish. The *Life of Wellington* has this note: "Lieut.-Colonel Henry Sturgeon of the Royal Staff Corps, whose name has been mentioned several times in these pages, was killed in this affair." "He was an officer of very superior merit" remarks in a note the gallant compiler of His Grace the Duke of Wellington's *Despatches*; "to which we may justly add, that he was one of the most gallant and zealous of soldiers. He commenced his military career in the Royal Artillery."

Throughout his long and distinguished future career the great Duke would never again need the advice of a Master Builder of Bridges. Sturgeon was born into this world to build bridges; he had built his last one and had produced that "prodigy of war" the bridge over the Adour. But surely his name and the existence of the Royal Staff Corps should not be forgotten by the Corps of Royal Engineers. He belongs to our family and with pride we can inscribe his name on the family tree. He is of our kin, as much as his great contemporaries, Burgoyne and Pasley.

An even more distinguished member of the Staff, mentioned in the *Notebook* as a bridge builder, was Colonel Sir Wm. Delancey, who was killed at Waterloo.

As for C. Rochfort Scott, when he was placed on half pay, his 20 years' previous service with the Royal Staff Corps proved no bar to his advancement. When stationed at Gibraltar he had spent his leave in Spain, and published a book with an account of his tours and excellent maps of his own making. So in the campaign in Syria in 1840 he was sent there and remained until the end of 1841 to complete the survey of the country. Subsequently he held various Staff appointments and when A.Q.M.G. in Dublin became a great friend of Prince George of Cambridge, afterwards Commander-in-Chief. Major-General C. Rochfort Scott was Lieut.-Governor of the Royal Military College, 1857-64 and Lieut.-Governor and C.-in-C. Guernsey, 1864-69. He was awarded a pension for distinguished service and died in 1872. The *p.s.c.* after his name was invisible, but he had graduated at a Staff College at Hythe.

Note by the Editor. The name of Lieut.-Colonel Sturgeon, Royal Staff Corps, was known to the Royal Engineers from a picture of his rope bridge across the gap in Trojan's bridge at Alcantara, which has been exhibited in the Royal Engineers Museum for many years. But a search among the exhibits, now stored for safety, has revealed a note-book of Captain George West, R.E. (whose service ranged from 1812 to 1833, and who served in the Peninsula and was one of the officers employed in bridging the Adour) which contains accounts of these bridges and whose notes are evidently taken from the same source as those of Rochfort Scott. These also are beautifully illustrated. He also shows an ingenious method of bridging a gap in a masonry bridge, with a note:—"Puento de Douro, de Simancas and 5 other bridges, repaired in this manner in the year 1813 by Lieut. W., R.E., by order of Sir Richard Fletcher."

THE USE OF GRADED STONE IN RUNWAY AND ROAD CONSTRUCTION.

By BRIGADIER C. H. HASWELL, C.I.E.

THE rapid increase in the strength of the R.A.F. just before war was declared necessitated a very large increase in the number of aerodromes and every contractor who had the plant and personnel capable of constructing aerodromes was kept fully employed.

The accepted specifications for runways consisted of P.C. concrete for those to take heavy loads and hardcore with a surface of tarmacadam for the lighter loads. Due to the very heavy consumption of cement for defence works, there was a great shortage and the supply of hardcore in the areas where aerodromes were being constructed involved long haulage.

The Air Ministry were obliged to consider other types of construction, using local materials available on the site or within a reasonable haulage distance. I was asked, therefore, to visit two sites which will be called Site I and Site II, to investigate the possibility of using the new system of soil stabilization. The report on the two sites was as follows :—

SITE I.

The area covered by the proposed aerodrome consists of sand dunes within 200 yards of the sea and between the seashore and a long creek. The sand dunes of blown sand are from 5 ft. to 12 ft. high and are composed of very finely divided sand. The flat area is covered with a sod, average thickness 6 in., composed of fine sandy loam, in which a good crop of grass is found. The sub-base consists of a pure fine sand with no binder. The mean level of the subsoil water table is approximately 6 ft., and strangely enough seems to be unaffected by variation in the tides. Adequate drainage is possible as there is sufficient fall to the creek.

SITE II.

This site is almost identical with Site I, though the sand dunes are not so high and the flat area is covered with gorse scrub. The seashore is about 200 yards away, but there is no creek. There is an existing system of land drainage which can be reconstructed and extended to cover the site of the runways.

Due to the fineness of the sand and the complete lack of binder in the sand, soil stabilization was considered out of the question and an alternative had to be found which would use local material to the fullest possible extent. Both sites are within very short distance of many of the best quarries in the country, and it was suggested to the Air Ministry that satisfactory runways could be constructed by the graded stone method, and by using this method the quantity of material to be hauled from the quarries would be very much reduced.

Graded stone is the macadam principle improved by the application of soil mechanics, and it has been found that a 5 in. thickness of graded stone is equal in strength to an 8 in. thickness of ordinary stone aggregate. Graded stone contains the scientifically correct proportions of fine material down to dust which fills up the voids and adds to the mechanical bond of the stone the strength due to the cementitious binder in the dust. It has the advantage that it is not affected by weather conditions, and the work can go on in fine weather, wet weather or frost. Rain during construction will considerably help the work, and the labour required is reduced to a minimum.

Sand, when contained, is as good a base as can be obtained, but as it existed on the site, wheeled traffic could not travel over it without forming deep ruts. It was therefore necessary to stabilize the top 3 in. by means of a quarry waste obtained from the overburden of nearby quarries, which contained the correct proportion of rough aggregate and clay. When rolled in, this stabilized surface was able to carry 3-ton lorries bringing in the graded stone for the surface layers.

The specification put forward to the Air Ministry was as follows :—

1. After completion of the formation of the runways and perimeter track, a 3-in. layer of quarry waste rolled in to stabilize the surface of the sand.
2. 4½ in. of graded stone, laid and consolidated in two layers.
3. Sealing of the surface with tar or bitumen, and adding a wearing surface consisting of a ¾-in. armour coat of ¾-in. chippings and bitumen emulsion.

This specification was accepted and the work was put in hand.

The first operation was the careful removal of the top soil to an average depth of 7 in. and stacking in dumps. This was necessary, as this top soil was wanted to cover the sand after all levelling was completed, to enable seeding to be carried out and to hold down drifting sand.

The second operation was the levelling for the formation of the runways, the removal of sand dunes where necessary and the filling of all low spots. This was done by mechanical tractors, scrapers, and graders.

Work on the stabilization of the sand surface with quarry waste was started as soon as sufficient of the formation had been completed to enable stone to be laid without a check.

Drainage is the most important part of the work, and this was started as soon as plant arrived on the site.

The actual earthwork and drainage were quite straightforward, except in one place where sheet piling was necessary to hold up the sides of the pipe trench, and it is not proposed to give any details.

The important part of the work was the graded stone base for the runways. The details of this and the description of the actual construction are taken from the diary of Mr. R. L. James, B.SC., A.M.INST.C.E., who supervised the work.

The graded stone work consisted of the following :—

Site I.—Three runways, making a total of approximately 160,000 sq. yds. Perimeter track approximately 3½ miles.

Site II.—Two runways each totalling approximately 120,000 sq. yds. Perimeter track approximately 4 miles.

SUBGRADE.

On Site I, comprising sand hills, rabbit warrens and some swamp, levelling operations commenced at the end of September, 1940. By December 7th, about 400 yds. by 50 yds. was ready for the start of runway construction. Level pegs were set at 50 ft. intervals along the runway, at the sides, centre and quarter widths. A camber of 1 ft. in 75 ft. was allowed for, or a cross fall of 1 ft. 6 in. the 150 ft. width. Quarry waste stone, ranging from 5 in. to 2 in. in size with about 20 per cent clay overburden, was laid at the rate of approximately 9 sq. yds. to the cubic yard and rolled with 8-ton tandem rollers until the rolled surface was 4½ in. below the top of the level pegs.

Any soft places were immediately noticed, and more quarry waste added until the levels were correct. Flat slate or shingle were found quite unsuitable.

The effect of the quarry waste and clay overburden was to stabilize the soft fine sand sufficiently to enable 5-ton lorries to travel over the surface without churning. The rough stone was dumped in heaps at about 7-yard intervals both ways, keeping about half a day's stone requirements always in hand. An attempt was made to spread the stone by means of a bull-dozer, but it was found that the tracks wedged the stone into hard mounds which required considerable labour to remove and spread evenly. Rough spreading caused loss of stone and lack of stability.

Spreading was therefore done by hand. The gang consisted of from 20 to 40 men, spreading from 7,000 to 18,000 sq. yds. per week, depending on weather, runway formation, and stone transport available. At the time transport was very scarce and unreliable, which accounted for the small out-turn. With adequate transport the yardage per week could easily be doubled or even trebled. The average worked out to 12,400 sq. yds. per working week. Three or four men from the gang were kept back to fill up any depressions or weak spots and to repair any surface damaged during rolling. The average yardage per cub. yd. of quarry waste worked out to approximately 7.5 yards.

On Site I drainage had not been completed when the start was made on stabilizing the subgrade. Consequently, in the marshy places rolling with heavy rollers if continued too much was apt to squeeze the wet sand up to the top of the quarry waste.

This shows the importance of getting the drainage in first. On Site II an adequate drainage system had been completed before the sub-base was laid which made it possible to use 10-ton rollers and thus provide a very much firmer base.

The amount of labour required to turn out at least 40,000 sq. yds. of finished sub-base per week would be three gangs of about 30 men each.

Graded Stone Work.

Runways.—The graded stone was placed in two layers, each separately consolidated and finished.

"A" Coat or Base Coat.—On top of the quarry waste base, graded stone 1½ in. to ¼ in. was spread at the rate of 13.4 sq. yds. to the ton. The stone was tipped from lorries and spread in position to rough levels by an 8 ft. grader blade. On the top of the dry stone, granite or limestone fines ¼ in. to dust was spread by grader blade at 29 sq. yds. to the ton. Two passes were then made with chain and spike-tooth harrows, biting 1½ in. into the surface, thus mixing the fine material in dry.

Two trips were then made at about 4 miles per hour with a 2,000 gallon water tank, discharging altogether about 1 gallon of water per sq. yd.

A further two or three passes with the chain and spike harrows, plus grading to correct levels with the grader blade, completed the mixing. Rolling then started with 8-ton tandem and 10-ton steam rollers and continued until marking ceased. This degree of compaction was reached more easily in drying weather. The result was a firm, smooth, and finely graded surface on which the heavy lorries bringing stone travelled easily without marking. The thickness of this "A" Coat after being consolidated was, by inspection, 2½ in.

"B" or Top Coat.—This consisted of 1½ in. of stone 1 in. to ¼ in., granite or limestone, whichever was available. It was spread by grader blade at 15.4 sq. yds. to the ton, followed by fines ¼ in. to dust at 42 sq. yds. to the ton. Scarifying with harrows, watering, grading and rolling were then carried out as for the "A" coat. Limestone is preferable to granite for this layer.

Progress.—This depended entirely on available transport and stone supplies. On the best days, up to 4,000 sq. yds .were finished. With adequate transport and stone supply, there would be little difficulty in constructing from 5,000 to

6,000 sq. yds. of finished sub-base and top layers of graded stone per day, and at this rate of construction not more than 120 men would be required.

For the same area of concrete construction, a much larger amount of labour would be required, unless the new elaborate American concrete-laying machines were available.

Armour Coat.—Graded stone being porous, it is necessary to seal it against penetration of surface water, and also to give it a wearing surface to enable it to stand up to traffic.

Sealing was done with a spray of low viscosity tar-bitumen compound laid hot at a temperature of 180-200° F. at the rate of 4 yards to the gallon. This penetrated at least ½ in. into the surface. When the seal coat had dried out, a ¾-in. granite armour coat was laid, constructed as follows :—

¾-in. granite chippings were spread on the sealed base at 60 sq. yds. to the ton, one stone thick. Two days were allowed for the evaporation of the flux in the cutback seal coat. The ¾-in. chippings were then sprayed with quick-breaking bitumen emulsion from spray tanks at 3 yards to the gallon, and immediately covered with ⅜-in. granite chippings spread at 90 sq. yds. to the ton. Rolling was done at once with 3-ton rollers and, ten minutes later, with 8-ton tandem rollers. The following day bitumen emulsion was again sprayed at 4 yards to the gallon, followed by dusting with stone dust and rolling. This final coat completely sealed the surface. If very heavy traffic is expected, it would be better to increase the thickness of the armour coat to 1 in. or 1½ in.

GRADED STONE.

One of the best authorities on graded stone work which has been used in New Zealand, is Mr. F. W. Hanson, of The New Zealand Main Highways Board, and his specifications have been used as a guide. He maintains that to get tensile strength, it is essential to incorporate in the stone about 30 per cent of clay. Undoubtedly greater strength will be obtained in a climate where sufficient drying out is possible, but from experience it has been found that in the British climate sufficient drying out cannot be obtained. Therefore the percentage of 200 mesh material in the fines was reduced. Cement could have been added to the fines, but it was considered that cement would produce a brittle base lacking in the flexibility of the graded stone and it was not used.

Both granite and limestone were available from local quarries, and the grading was as follows :—

Retained on	1½"-¼" *Granite*	1"-¼" *Limestone*	¼"-Dust *Granite*	¼"-Dust *Limestone*
1" Square	26.4	–	–	–
1"-¾"	60.7	50.1	–	–
¾"-½"		35.5	–	–
½"-¼"	11.5	12.5	–	–
¼"-10 mesh	–	.8	36.5	36.4
10-50 ,,	–	·4	48.0	54·4
50-200 ,,	–	·4	7·1	3·1
Passing 200	–	.1	4·9	3·7

The final consolidated thickness of the two coats of graded stone was 4½ in. After consolidation had been completed, three samples were cut from areas where the surface seemed particularly hard. The mechanical analysis was found to be as follows :—

	(1)	(2)	(3)	*Mean*	*c.f.Hanson*
Retained on—					
1" Square	6.7	10.1	12.5	9.8	30
1"-¾"	25.4	24.6	26.4	25.5	
¾"-½"	20.3	15.9	14.2	16.8	23
½"-¼"	8.4	4.5	5.2	6.0	
¼"-10 mesh	11.6	17.3	16.6	15.2	14
10-50 ,,	19.6	21.4	17.1	19.3	13
50-200 ,,	1.3	1.2	1.0	1.2	8
Passing 200 mesh	1.5	0.7	1.0	1.1	12
	94.8	95.7	94.0	94.9	100

These figures conformed very well to Hanson's grading except in the fine sizes. The question was whether the lack of clay would weaken the resultant mass. To test this, cylinders 2 in. diameter and 4 in. long were made up from the ¼" dust material, compressed and dried for two days in air. These were put into a press and crushed. It was found that, unsupported, they would take a load of 105 lbs. per square inch. This was considered sufficient to take the heaviest load, and proves the interlocking strength of the angular material.

To guarantee that the specification of the grading was being adhered to in the quarries, two sieve tests were made each day of the incoming stone and occasionally tests were made from the work under construction. Brass wire sieves with square mesh of the B.S.S. type were used to ensure a standard measurement.

Construction Notes.

Each layer, sand, quarry waste base, " A " coat, " B " coat was brought to the correct shape and level as the work went on, in order to ensure that the levels were correct on the finished surface. A comprehensive drainage system had been installed, which is the first essential, but in one or two places base weakness was shown up by the heavy rollers marking the surface. At these points lines of 6-in. porous pipes were installed at a depth of 2 ft. 6 in. to 3 ft., connecting with the french drains on the sides of the runways, and firmness was soon obtained.

Stone was supplied in tipping lorries fitted with adjustable tail boards, when they could be obtained. If these are not available, it is necessary to keep a small gang on the site to empty non-tipping lorries.

During summer months keen supervision is necessary to prevent roller drivers wasting time by driving backwards and forwards over perfectly dry stone.

If completely dry, the stone dust surface should be sprayed with water, well rolled and then left to dry. Sometimes in a small area, continual rolling will not produce any cohesion. This will show incorrect size grading, and it should be corrected by a few loads of 1 in. to ½ in. stone or ¼ in. dust. It is easy to see what is required. If the surface looks open, use the fines.

The " A " coat surface should be throughly dust bound, but the top " B " coat surface should show clean stone with the grit and dust wedged in the angles between the stones. This makes for better priming with hot tar-bitumen compound, and gives a sound key for the armour coat.

The dust required for the final blinding of the armour coat should not be dumped in heaps on the surface of the " B " coat, but should be spread straight from lorries on the final bitumen spray. If dumped in heaps, some dust will be left on the surface which will destroy the key for the armour coat and render it liable to peel under traffic.

General.

The runways were designed for use by light aircraft, but Site I has stood up to the heaviest loads and has shown no sign of failure through two winters. One runway was subjected to the crash landing of a heavy bomber without undercarriage and suffered no damage.

For use by the very heavy bombers now in service, the combined thickness of the "A" and "B" coats should be increased to a minimum of 6 in., and the armour coat surface to $1\frac{1}{2}$ in., to give the extra weight necessary to hold it down.

The great advantage of this type of construction is that it can be carried on in all weathers. Rain and frost do not affect it and there is no setting to be broken up by frost heave.

Most of the work is done by machines which are simple and the minimum amount of labour is required, probably less than for any other type of construction. The cost worked out at least 3s. per sq. yd. less than for cement concrete, but to ensure this, the site must be within a reasonable distance of an adequate stone supply. Much less transport is required than for stone pitching and tar macadam.

On both Sites I and II, the perimeter track was given a lighter specification than the runways. In my opinion this is unsound, as from experience it is found that the perimeter track takes much more traffic than the runways, and has to stand up to much heavier hammering from petrol tanks and heavy lorries. The perimeter track should be given the same specification as the runways and possibly a heavier surfacing. Lorries are inclined to run in the same track and subject a narrow width to a greater load than the runways are ever likely to get. The greatest pressure to which an area can be subjected by a landing or moving plane is approximately 100 lbs. per square inch.

Due to the success of graded stone on a sand sub-base on the aerodromes which have been constructed, the idea seems to be prevalent that this specification can only be used on sand, but this is not the case. It will give the same results on clay and has many advantages.

Before laying the graded stone, the subgrade is first stabilized. In the case of fine sand the agent is quarry waste with a 30 per cent. clay content. The clay binds the non-cohesive sand together and forms a sound load-carrying sub-base.

In the case of a clay subgrade, this would be first stabilized by mixing-in sand and gravel until the clay content is reduced to 30 per cent. The gravel and sand would be spread on the surface and punched in by means of sheepsfoot tamping rollers until a thorough admixture is obtained.

Ordinary clay will shrink as much as 27 per cent. on drying, causing great movement, but by mixing-in sand and gravel the shrinkage can be reduced to under 3 per cent. By this means a perfectly stable base can be obtained. The amount of sand and gravel required will depend on the actual clay content of the soil. This can be ascertained by a very simple sieve test, and sufficient sand and gravel must be spread to ensure that the top 6 in. of the soil has not more than 30 per cent clay content. If the clay is very colloidal, a greater depth should be stabilized.

If stone pitching is laid on a clay subgrade, the clay under the action of traffic will gradually work its way through the interstices of the pitching until it forms a cushion between the pitching and the tarmac surface, causing disintegration of the surface. This was found to be the cause of trouble on an aerodrome where hardcore had been laid straight on the top of the clay without first stabilizing it.

One great advantage of the graded stone specification on a clay subgrade is that by scientifically grading the stone down to dust, the density is so great that the clay is held down, and cannot work through. Flexibility is another point in its favour, as slight movement can be taken up without cracking and distortion. It forms a raft which has a bridging effect, as was shown in one case on the N.W. Frontier of India. After a flood which washed out a 5-ft. bank on which a road was aligned, a 9-in. thickness of consolidated crusher-run limestone carried a heavy car over a 10-ft. gap.

An outstanding example of graded stone on clay can be seen in the S. Command. An old fair ground in one town was allocated as a parking area for the heavy M.T. of a division. The area was a grassy field on a heavy clay soil about 3½ acres in extent, bounded by roads and buildings, with an approach from one road. It was on a slight slope, and there were springs near the top. After a very short time in use, the area became a sea of heavy mud, with deep ruts. Transport was continually getting bogged, and the damage to vehicles, particularly as regards clutches, was getting so serious that the abandonment of the area was considered.

I was asked if I could provide a cheap solution, and I suggested graded stone. As expenditure was to be cut down to the minimum, no drains were put in, though the area was waterlogged, and no preliminary preparation of the ground was done with the exception of the smoothing down of the ruts with a grader blade.

On this wet and muddy base, 6 in. of graded stone 1½ in. to dust was spread and rolled with first a light and then a heavy roller until the material was well packed. It was left for a few days, given a light spray of bitumen emulsion to keep down dust, and then handed over for use.

For 3 years it has been subjected to continuous hammering by heavy M.T. including testing of brakes, and has stood up to the strain in spite of having had no maintenance. To reduce the cost, no surfacing was given and there was no drainage, which, due to roads and buildings, would have been difficult and expensive.

There is no sign of failure or cracking or of the clay having worked through, and the only damage is two small potholes which would be expected on a water-bound road which had not been maintained.

The area is still taking considerable traffic, and the cost was under 3s. 6d. per sq. yd.

THE R.E. RECORDS SECTION, G.H.Q. 2ND ECHELON, B.E.F. 1939-40.

By MAJOR R. WINDERS, R.E.

1. INTRODUCTORY.

IN the promotion examination of March, 1937, the paper on Organization and Administration contained a question on the preparation of Part II Orders in the field. The examiners' comments published later in the year referred to this question as having been badly answered by the few candidates who attempted it and said that most of them seemed very hazy as to the functions of the D.A.G's office at the base. By a lucky fluke, the writer, who took this exam., had glanced at the appropriate sections in *F.S.R.* Vol. I, the night before the paper, and produced the right answer. Little did he think that three years later he would be in charge of the R.E. Records Section of that very office and responsible for compiling all Part II Orders for some 40,000 R.E. Other Ranks of the B.E.F. These notes are intended to give some slight idea of the workings of the Section and a few hints as to how, by rendering various returns accurately and promptly, an O.C. unit can save himself endless trouble and also benefit his own troops. G.H.Q. 2nd Echelon performed other important duties besides Records work and preparation of Part II Orders, but these notes are confined to those subjects. 2nd Echelon procedure has since been modified in a few minor particulars, but the general principles hold good.

2. History.

G.H.Q. 2nd Echelon (usually referred to by its telegraphic address of O 2 E) was formed at Aldershot on the outbreak of war, went overseas some ten days later, and settled at a small watering place in the west of France. Difficulties were experienced owing to the long time (up to 5 days) taken by letters and returns to reach O 2 E from forward units, and at the beginning of December, 1939, it was decided that O 2 E should return to England. After a careful reconnaissance of various locations offered, a town in Thanet was chosen, and by the middle of the month O 2 E, less the Reinforcements Section, which moved to H.Q., L. of C., was settled in a large hotel, with the staff billeted in various smaller hotels and boarding houses near by. Teleprinters were installed, giving direct communication with the War Office and with G.H.Q., B.E.F., and it was also possible, though not easy, to telephone to G.H.Q.

After the evacuation of Dunkirk O 2 E was moved to a West Country town, and worked there under considerable difficulties regarding accommodation until it was disbanded on 31st July, 1940, the B.E.F. having ceased to exist as such.

3. Personnel.

As no 2nd Echelon existed in peace, an establishment had to be improvised. In the case of the R.A.C., R.A. and Infantry Records Sections, each battalion or regiment sent its orderly-room serjeant to deal with its own returns. In the case of Corps such as R.E. and R.A.S.C., whose units had no orderly room serjeants, miscellaneous clerks, usually reservists, were provided from various sources. The officers were almost all from the retired list.

As the B.E.F. expanded, O 2 E was augmented, but there was a considerable time-lag in the case of Corps. In March, 1940, the War Office approved an establishment for Records Sections of Corps on a scale of 1 clerk per 600 Other Ranks overseas, and 1 Officer and 1 W.O. Class I as supervisory staff for each 50 clerks. An elaborate system of promotion was introduced among the clerks of each Section, the ranks and numbers of each rank depending on the total number of clerks in the Section. By this time, A.T.S. personnel had been introduced, further complicating the question of promotion, as at one time A.T.S. N.C.O's were held to count against the total number of N.C.O's permitted by the establishment.

The chief difficulties experienced were the time-lag already mentioned and the need for specially training such clerks as were posted once they had arrived. The establishment of a Section in April, for instance, was fixed by the strength of the Corps overseas on the last day of March, no matter how many personnel embarked in April. The section was invariably below establishment, and many of the clerks were new arrivals learning their job. When the actual strength of the R.E. in the B.E.F. justified 80 clerks on the 1 to 600 scale, the establishment of the R.E. Records Section was 72 or so, and the actual strength about 67, seasoned hands, learners and passengers all included.

The quality of some of the clerks was very indifferent. A unit in the U.K. would be instructed by Home Records to post a clerk, medical category "C" if possible, to O 2 E, and the O.C. did not usually send his best clerk. One, in fact, furnished by a field unit, was not only C3 but almost illiterate, and was returned forthwith as unsuitable. The A.T.S. clerical staff were a mixed bag, some good, others almost useless, as was usual at this time, which was before the review carried out to ensure that telephonists were not employed in kitchens, or cooks as typists.

When the establishment justified the appointment of a second officer, a R.T.R. subaltern (A.O.E.R.) was posted from R.A.C. Records, Canterbury, and he proved to be a tower of strength during the rush period which then lay just ahead, having had some years of experience in the Canterbury office.

4. Organization of the R.E. Records Section.

The writer took over on the 1st March, 1940, from a Sapper Major who had retired shortly before the war, but had been recalled on mobilization. His policy, which the writer tried to continue, was that he was not merely a Records officer. He considered himself to be the young uncle of the R.E., B.E.F., the father being O. i/c R.E. Records (referred to hereafter as "Home Records") who had several other children to care for and had asked his younger brother to act as guardian of the eldest child, who had gone to France for a while. A good deal of work was carried out by d/o correspondence, especially with the Os.C. non-regular units, whose knowledge of official procedure and channels of communication could not be extensive. This point will be mentioned again.

The Section organization was similar to that developed in the B.E.F. in 1914-19 and was on a Corps basis, not by units or groups of units, another point which will be referred to later. Three sub-sections were formed, known as R.1, R.2 and R.3, clerks being interchangeable between the sub-sections if necessary. A drill had been evolved for dealing with casualty returns, and the various stages were as follows :—

(*a*) Each entry was first checked by R.3 against the Card Index to ensure that the number, name and initials were correct. The Card Index was compiled from units' embarkation returns and nominal rolls, and was continually kept up to date from the casualty returns.

(*b*) Deaths, injuries, absence without leave and desertions were noted by R.1 for appropriate action. Cases of absence or desertion, it is good to know, were very rare indeed in the Corps.

(*c*) R.2 then analysed the returns, carefully checking such items as hospital admissions and discharges, "X" list personnel, punishments and trade tests, and prepared extracts for Part II Orders. These extracts were scrutinized by the N.C.O. in charge, a Staff Serjeant, nicknamed "The Editor," while his chief assistant was known as the "City Editor."

(*d*) When sufficient extracts were available in the case of any unit to justify issue of a Part II Order, a wax stencil was prepared in the typing sub-section of R.2, and the Editor's staff checked all entries against the extracts before the stencil was put on the duplicator.

(*e*) Copies were then run off and distributed to all concerned. One copy was sent to R.3, where the necessary entries were made in the Army Forms B 103, and in the Card Index. Any errors which might be discovered at this stage were noted for amendment in the next Part II Order for the unit. A.Fs. B. 103 were kept in loose-leaf binders by units or groups of small units, the forms for each unit being arranged in alphabetical order.

The object of this seemingly elaborate procedure was to produce as accurate a Part II Order as possible, and naturally there was a time-lag between the receipt of a casualty return and the issue of a Part II Order. When the Section was in France, dealing with Regular and other peace-time formations, and casualties were few, the lag was about 10 days. Later it grew to 3 weeks, which the writer considered reasonable, after taking into consideration the shortage in the Section of skilled clerks and also of typewriters, and the very haphazard way in which some units rendered their returns. He was constantly being urged to shorten the lag, lest operations begin in earnest and the office be swamped by long returns of battle casualties. He investigated the matter very carefully indeed, widened one or two bottlenecks, and satisfied himself that, not only was the Section working its hardest, but that the elaborate checking system was justified by the fewness of the errors requiring amendment. Other Sections reported at the A.A.G's weekly conference that by using more slapdash methods they were more up to date but did not mention the number of amendments they had to make. The writer has since learned that one or two of the other

Sections actually had a 6 weeks' time-lag, but their officers never brought this to notice.

After the invasion of the Low Countries, battle casualty returns began to pour in, and had to be dealt with urgently. As will be readily understood, accuracy in Part II Orders for battle casualties was of paramount importance, and mistakes in the returns were more frequent owing to the conditions under which they were prepared. All sections, especially R.1, which had previously had little to do, felt the strain, but bore it well, and cheerfully worked many hours of overtime daily. Clerks were switched from one sub-section to another as necessary, so that everyone was doing his or her fair share of the work.

Incidentally, it was a curious sensation to sit in an office in England and follow the battle casualty returns, noting the locations of the units. As might have been expected, the first deaths were in a Field Company in the front line, but they were immediately followed by long lists from General Construction Companies employed on maintenance of forward airfields, and from Docks Groups and Stevedore Battalions at the base ports. Air attack has completely altered the tradition of the last war that a job at the Base was a safe hide-out.

5. Reinforcement Demands.

When O 2 E moved to England, the Reinforcements Section, usually known as Reforce, moved to H.Q., L. of C., France, and co-operation between the Reinforcements and Records Sections became more difficult. Reinforcement demands were submitted weekly by units direct to both Sections, to Reforce for action and to O 2 E for statistical purposes. In the R.E. Section O 2 E, a Staff Serjeant and two A.T.S. clerks of R.3 dealt with these returns and reported direct to the O.C. Section, who scrutinized the demands closely. One Staff Serjeant was left in France as the R.E. clerk in Reforce.

By April, units who had not fully understood the purpose of the Reinforcement Demand had caused considerable confusion by demanding large numbers of tradesmen as reinforcements, regardless of their strength in actual " bodies," and an impression had been created at the War Office that in some inexplicable way the Corps in France was about 5 per cent below establishment. For instance, one Works group with a combined establishment of 790 odd had an actual strength of about 840, yet actually demanded 40 reinforcements by trades. The writer noticed this, dropped a reassuring hint in the right quarter, and prepared a circular memorandum to be issued to all R.E. formations in the B.E.F., explaining the reasons for the demand and for its various sections, and giving precise instructions as to how it should be compiled. To save time, the draft was submitted by d/o letter to Reforce, who suggested one or two minor amendments but agreed in principle, whereon the writer issued it. Unluckily for him, the Engineer-in-Chief, B.E.F., issued somewhat different (and, in the writer's opinion, not nearly so accurate) instructions on the same subject the very next day. Before these had even reached O 2 E, the Staff Captain R.E., Reforce, rang up from H.Q., L. of C., proposing a visit to O 2 E in connection with this and other matters, and asked whether O 2 E would meanwhile cancel their instruction by teleprinter, as the weekly demands were due next day. This was at once promised, and a short teleprinter message was despatched within the hour to some forty addresses all over France. The writer checked the layout of the message with the Signal-Master at O 2 E, but, unfortunately, both forgot the magic postscript " All informed," with the result that, fully a month later, O 2 E received a reprimand from the A.G's office, B.E.F., for having clogged the entire Signals network in France for hours with an administrative message made up almost entirely of addresses. Fortunately this was during the " Phoney war," and did not seriously affect the conduct of operations.

Staff Captain, R.E. Reforce, flew over from France, and in a morning's amicable discussion he and the writer settled outstanding points which might have taken weeks of correspondence. A general agreement was reached that reinforcement in terms of " bodies " was a Reforce responsibility, that reinforcement or replacement of W.O's, N.C.O's and certain highly skilled specialists *by name* was a matter for O 2 E, and that exchanges of tradesmen between units to adjust surpluses and deficiencies were primarily for Reforce to deal with, subject to O 2 E concurrence in certain cases. Staff Captain R.E., was unfortunately killed in a motor accident a week later, before the agreement had been finally approved by the respective A.A.G's. It naturally fell into abeyance when the *blitzkrieg* began, but was sound in principle.

Another bugbear which died just before Dunkirk was the wholesale transfer between various arms of the Service of tradesmen under the high-sounding title of " Economic Use of Man Power," which caused many a headache at both Reforce and O 2 E.

6. Casualty Returns.

Part II Orders are the finished product produced from the raw material of a unit commander's casualty returns, and it was O 2 E's duty to prepare them. Many a unit commander must have cursed on receiving " observations " signed by the writer, whereas a little more care on his own part, or that of his clerks, would have obviated all the bother. O 2 E was all out to help units, but units did not always realize that they themselves must co-operate.

While O 2 E was in Thanet, the writer periodically lectured to the officers of new Construction Companies being formed near by. Each member of the audience received and kept a copy of the writer's notes on the various forms rendered to O 2 E, together with a specimen of each form (*not* for retention) exactly as received from units and marked by O 2 E clerks. Each copy of a form was, of course, different from any other, and, having asked the audience to look for possible mistakes or to ask questions about each form in turn, the lecturer was able to make his points easily. The Inspector R.E. paid a visit to O 2 E after inspecting some of these Construction units, and was so convinced of the necessity for co-operation by units that he asked whether the 2nd in Command and pay N.C.O. of every company ordered to France might be shown round shortly before embarkation. This was actually done in a few cases before the *blitzkrieg* broke out, and both sides profited by having met each other.

The following suggestions regarding submission of returns are offered for the guidance of unit commanders :—

(*a*) Legibility in returns is all-important. If no typewriter is available, black pencil in a neat round hand, with all names in BLOCK CAPITALS, will do quite well. Indelible pencil should NOT be used, as mails often get soaked with rain or sea water.

(*b*) Number, rank, name and initials should all be given. One unit showed on its embarkation return an entry of " Smith." A routine request for Spr. Smith's number and initials evoked an indignant protest that " Smith " (number and initials given this time) was the C.S.M. of the unit, and what did O 2 E think it was doing ? The retort courteous was " How were we to know if you didn't tell us ?"

(*c*) Casualties should if possible be grouped by types, *e.g.*, promotions, leave, punishments, etc., and the names in each group shown in alphabetical order. This greatly simplifies the preparation of a Part II Order, and in turn helps the Regimental Paymaster and R.E. Records.

(*d*) When punishments are reported which affect pay, a Minor Offence Report should be attached to the casualty return.

(*e*) There is an inevitable time-lag between the occurrence of a casualty and the Regimental Paymaster's action on such an item as increasing a family allotment. In cases where hardship may result, a special casualty return for such items sent to O 2 E with a request for immediate action will always receive prompt attention.

7. DEMI-OFFICIAL CORRESPONDENCE.

Demi-official correspondence *rightly used and promptly handled* can be most valuable in avoiding useless official correspondence and in solving knotty problems, as a unit commander can ascertain whether it is worth his while to put a case forward officially, or can bring to light some grievance for early remedy.

An actual case was that of a unit, several members of which had just returned from home leave. The serjeants had found that their wives were getting the same separation allowance as those of the sappers, and in some cases were in sore straits financially; the Regimental Paymaster had stated officially that, until the N.C.O's had been promoted War Substantive serjeants in O 2 E Part II Orders, he was unable to increase the allowance; the serjeants (and their wives) naturally had a grouse, as, although the three months' qualifying service for War Substantive rank was almost completed, the Part II Order would not, in the ordinary course of events, appear for several weeks, and the Paymaster, whose staff was also overworked, would again take weeks to act on it. The O.C. wrote d/o to O 2 E asking what was the best thing to do. A d/o reply suggested that he should publish a special casualty return immediately on the expiry of the three months, reporting the grants of War Substantive rank, and forward it with a covering letter asking for urgent action as already promised by d/o. He did so, the casualty return was given first priority, and within 48 hours of its receipt, the Regimental Paymaster received the appropriate Part II Order together with a polite official request for similar urgent action.

d/o letters must, however, be clearly recognizable as such, so that they may be opened and acted upon should the officer to whom they are addressed have changed his appointment or be absent for some reason or other. One unit addressed an important d/o request to the writer after evacuation from Dunkirk, but the envelope was marked "Private and Confidential" instead of "d/o". The letter took exactly a month on its way from Edinburgh to a London address, and, in any case was about a matter which could only be dealt with by Home Records.

8. EVACUATION PROBLEMS.

The R.A.C., R.A. and Infantry Records Section of O 2 E had a comparatively simple task, both before and after the evacuation of France. A regiment or battalion, when embarking, sent its orderly-room serjeant complete with papers *and typewriter* to O 2 E, so as to handle the unit's Part II Orders. Not only was he already trained in the duties, but he knew all the W.O's and Serjeants and many of the Other Ranks personally. This proved invaluable on the hurried evacuation of the B.E.F.

The War Office "Dynamo Plan" in connection with Dunkirk and the later plan for the units who were evacuated from France detailed the points at which units would reform in the U.K., *e.g.*, 2 R.F. at X. Thereon the orderly-room serjeant of 2 R.F. packed his records and typewriter, proceeded to X, and carried on with the reorganization of the unit. Corps, on the other hand, were sent to different centres (in the case of R.E. six or seven) by types of unit, *e.g.*, Fd. and Fd. Pk. Coys., Gen. Const. Coys., Docks Groups, etc. Reception camps throughout the U.K. were instructed to sort out all arrivals and dispatch them to these centres. At the port of disembarkation, the Movement Control Staff had barely time to fill each train with odds and ends and send them off to, say Y, before an empty train pulled in, to be filled and despatched in turn. The result was that 24 hours later 500 men detrained at Y, and among them might be 2 dazed sappers of some unit which the harassed Adjutant could not classify, so he appealed to his Area Commander, to O 2 E or to Records for assistance.

If and when the sappers arrived at their correct destination, they were checked in, not by a unit orderly-room serjeant, but by a representative of R.E. Records O 2 E, who did not know them from Adam, and had only the nominal rolls and A.F's B. 103 of a group of units on which to work. Unit Commanders seemed suspicious of the O 2 E representatives, for, though the clearest instructions had been given that all personnel shown on the nominal rolls who could not at once be satisfactorily accounted for were to be reported to Home Records as "missing," Commanders often flatly refused to sign the Casualty Returns prepared for them by the O 2 E representative, giving as reason the possibility that the men might turn up any day, and that it would be unfair to alarm their relatives. Needless to say, Records took great care not to issue telegrams until it could reasonably be assumed that a man was definitely missing. On the contrary, one man was officially reported to O 2 E as "killed in action," so O 2 E informed Records. A week later Records wrote to O 2 E, gently suggesting that a mistake *might* have been made, as the man had just written from a leave address to the Regimental Paymaster, asking for an advance of pay to spend while on leave.

The nominal rolls *which had been furnished by the units themselves on original embarkation for France* were admittedly 3 months out of date on an average and were due for revision any day, but in numerous cases the O 2 E representative was told that Spr. Snooks had never left England, and that L/Cpl. Buggins had never been in the unit at all. This did not give an impression of great efficiency on the part of the unit, even after all allowances were made for the loss or destruction of all their documents during the campaign and evacuation.

9. Suggested Improvements in R.E. Records Section, O 2 E.

The ideal solution of these and other difficulties would have been the despatch to O 2 E of an "orderly-room serjeant" by each C.R.E's command or equivalent on embarkation. One T.A. Division which actually had such a serjeant, instructed its C.R.E. to send him to O 2 E, although the C.R.E. protested vigorously. The serjeant in question and his excellent new typewriter were most valuable assets to O 2 E.

This procedure being impracticable unless the organization of the Corps is amended, a good alternative would have been a reorganization of the Records Section such as was being worked out and would have been introduced in August, 1940. The Section would have been split into small sub-sections, each dealing with a group of units and producing its own observations, Part II Orders, etc., but using a central Card Index which would enable any queries to be answered quickly. After a while, the sub-section would have become familiar with certain names, Spr. A. for instance, celebrated for drunkenness, or Sjt. B., who had made his promotion from sapper by stages of one stripe per 3 weeks.

Without some such personal interest, even the thought that the Section's work is vital to the Corps tends to lose its appeal, and the mechanical nature of Records work becomes after a time soul-shattering in the extreme to any but those of the most unimaginative temperament.

10. Conclusion.

When O 2 E was disbanded, a few key men were sent to R.E. Records to clear up any points then outstanding, or any others which might arise, and the writer and the remainder were posted to the R.E. Depot for disposal. The Second-in-Command was whipped away at 24 hours' notice to a special appointment and the writer was unable to say good-bye to him or thank him. The writer has since met one or two of his old staff, and has spoken to others on the telephone, and each time has been impressed by the fine team spirit which had evidently grown up among them, though they had, so to speak, originally been gathered in from all the highways and byways of the Corps. He will not soon forget the astonished, but delighted, expression on the face of an A.T.S. private of the Section whom he encountered by chance in London in June, 1941, and whose name he was fortunate enough to recall on the spur of the moment. He considers that the Section may feel proud of having done a monotonous but very valuable job of work for their comrades overseas, though the latter may not always have fully appreciated this at the time.

THE PROTECTION AND DEMOLITION OF OIL INSTALLATIONS.

By LIEUT.-COLONEL C. E. HOWARD-VYSE, M.B.E., R.E. and
LIEUT.-COLONEL J. V. DAVIDSON-HOUSTON, M.B.E., R.E.

1. INTRODUCTION.

THE vital importance of oil to belligerents is well understood. It has to a great extent influenced the strategy of the Axis Powers. Germany, possessing no natural petroleum, was driven first to assert her control over Rumania, and then, after reaching vainly for the oilfields of Iraq and Persia, to launch a gigantic expedition for the occupation of the Caucasus. Japan, almost entirely dependent on imports of war material, was compelled to attack the Dutch East Indies in order to secure her supply of this essential commodity. Considerable experience has thus been gained in the preparation and execution of schemes for the denial of oil to the enemy, and it is considered that this experience should be made more generally available in connection with the following operations :—

(*a*) Demolitions to deny our oil to the enemy. At this stage in the war it may reasonably be hoped that the situation in Persia, Iraq and the Levant is sufficiently favourable to render such an operation improbable.

(*b*) Raids on oil installations in enemy hands.

(*c*) Measures to protect oil installations against enemy raids or sabotage by enemy agents.

(*d*) Measures to prevent or minimize damage to oil installations captured from the enemy. When Bardia was taken after General Wavell's victory at Sidi Barrani, parties of sappers with the leading British troops prevented the destruction of the water supply by the Italians, and analogous tasks may frequently fall to the lot of the Engineers in the pursuit.

The operation and destruction of oil installations both require considerable training and experience, and should as far as possible be left to the direction of technical experts, such as the employees of the oil company concerned. In the case of enemy establishments, however, the Army may have to rely almost entirely upon the Engineers ; in any case the bulk of the work will devolve upon Engineer personnel.

The object of this paper is to outline the principles involved, and to give Royal Engineer officers enough information to enable them to co-operate with technical experts.

2. GENERAL DESCRIPTION OF OIL INSTALLATIONS.

These may be classified for military purposes as :—

(*a*) Fields.
(*b*) Pipe lines.
(*c*) Refineries.
(*d*) Storage tanks.
(*e*) Railway tank cars.
(*f*) Tankers and barges.

(*a*) *Fields.*—Oil is found at varying depths beneath the earth's surface, very often in the foothills of a great mountain range, e.g., Carpathians, Caucasus, Bakhtiari hills. The following is the usual procedure when it has been decided to tap a reservoir of oil.

A four-legged structure, known as a " derrick," is erected over the site ; it may be constructed of wood or steel. A hole is bored by means of a boring tool suspended by a steel cable which passes over a pulley at the top of the derrick

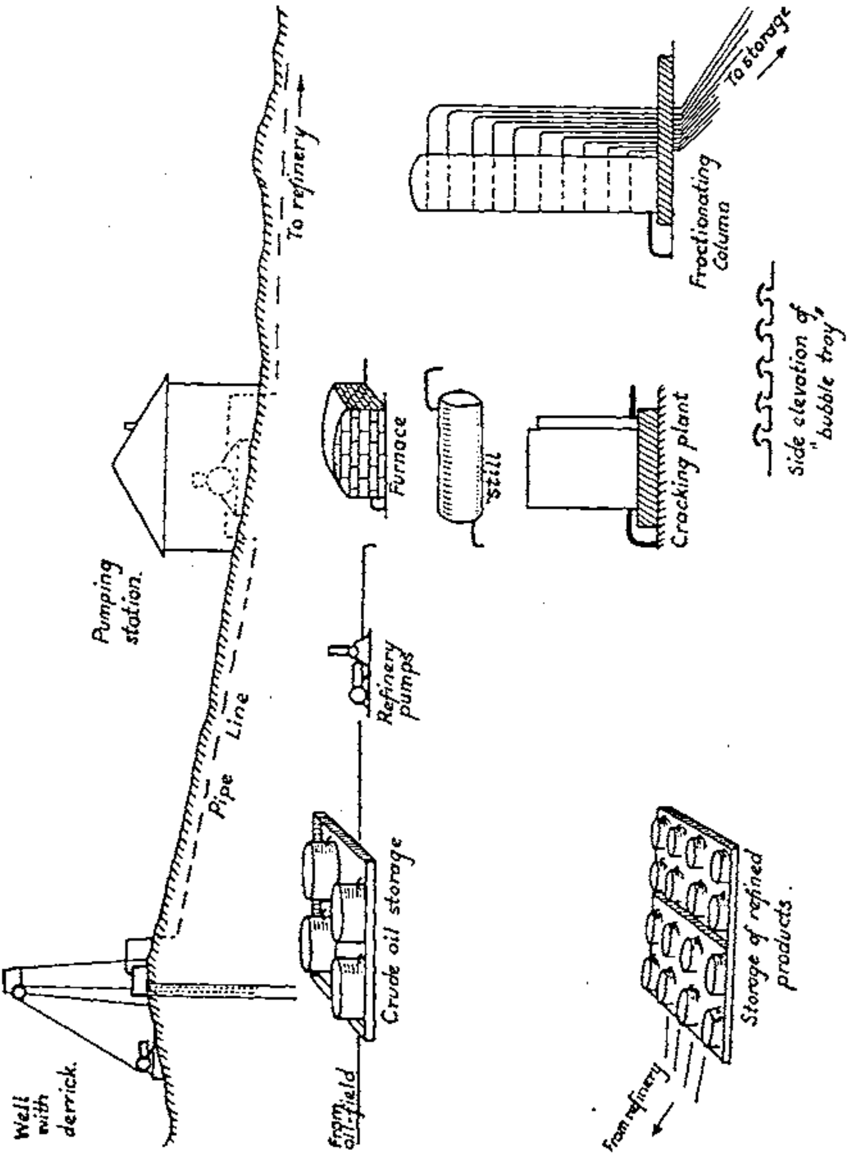


DIAGRAM OF IMPORTANT TARGETS IN AN OIL INSTALLATION.

and is operated by an oil engine on the ground. The process resembles the sinking of a deep-water well. As the boring proceeds, the tool is periodically detached and a length of steel casing lowered into the hole, its internal diameter being about 8 inches. When the well has reached the required depth, steel tubing is lowered into it; this tubing may have an internal diameter of 4 inches, and is used for the withdrawal of the oil.

As in the case of water, the well may be "artesian" or may require pumping. It often happens that it begins by flowing under its own pressure, which gradually drops as the well is worked, until the oil needs to be lifted by artificial means.

The "flowing" or "pressure" well, which starts by gushing out of the ground, is at once capped, and the flow thereafter controlled by means of a system of valves nicknamed the "Christmas tree." This is so designed that the oil is prevented from flowing out of the well with damaging velocity, and its proper operation requires expert knowledge.

The two main methods of extracting oil by mechanical means are pumping and "gas-lift." In the former type a reciprocating pump is lowered into the well and operated by an oil engine or electric motor at the surface. In the "gas-lift" type, oil-gas is introduced into the well under pressure and forces the oil to ground level.

Many wells, as in the Rumanian fields, are as much as 10,000 feet deep; this gives some idea of the length and weight of tubing and of pump-rods suspended in the casing.

(*b*) *Pipe Lines.*—The crude oil is conveyed to the refinery by steel pipes of large diameter over distances which are often very great. The pipe line from Ploesti to the Black Sea port of Constantza, for instance, is nearly 150 miles long, while the length of the Kirkuk-Haifa pipe is about 600 miles. The carriage of oil over such distances requires relays of pumping stations at intervals depending upon the gradients and the rate of delivery, and the protection of the pipe line involves the provision of small garrisons at the pumping stations and constant patrolling between them.

(*c*) *Refineries.*—On arrival at the refinery the crude oil is run into storage tanks until required for processing. At this stage it is a viscous black liquid which requires pre-heating to render it suitable for treatment in the plant. The heating is carried out by running the oil through steel pipes enclosed in a brick furnace, after which it is split up into its constituents by fractional distillation.

Fractional distillation takes place in a vessel known as a "fractionating column" or "bubble tower." This is a cylindrical steel structure which may be eighty feet in height and fifteen feet in diameter. Inside are steel trays at various heights, one above the other. Each tray is pierced by a large number of holes, the edges of which are turned up so as to project slightly above the rest of the tray. Heated crude oil is admitted at the foot of the column, giving off gases which pass upward through the holes in the trays. The lighter products, such as motor spirits, rise to the upper part of the column, where they cool and condense, running down the wall on to one or other of the trays, according to their respective volatilities. Vapours condensing upon a tray are prevented from dropping back through the holes by the turned-up edges and by caps or "bubbles" projecting over them. The upper surface of each tray thus becomes covered with a liquid fraction of petroleum, which is run off to storage by a pipe leading from the side of the tower. In the same way such fractions as paraffin and lubricants condense upon lower trays, while Diesel and furnace oils are found near the bottom.

Another process employed is "cracking." The character and proportions of the products of fractional distillation are determined by nature, and these may not be suitable for industrial or military purposes. By further heating it is possible to regroup the hydrocarbons to form oils in quantities which would not be given by distillation. Such an operation is known as "cracking," and is performed in a series of closed steel vessels.

The movement of oil through the plant is dependent on a large number of pumps, which are driven electrically or by oil engines. In most refineries motive power is supplied by electricity.

All modern refinery plant is laid out with a view to minimizing the risk of fire; units are generally duplicated and dispersed, and fire mains run to all parts of the installation.

(*d*) *Storage*.—The refined products are run into tanks, which are usually grouped in small batches surrounded by low walls or banks to prevent flooding in case of a damaged or leaking tank. Tanks containing volatile oils are often fitted with a floating roof to reduce the risk of explosion due to the presence of air above the liquid. During the present war it has become a common practice to surround tanks with splinter-proof concrete walls or to store oil in underground reservoirs.

(*e*) *Railway Tank Cars*.—Resort is sometimes had to railway transport, in substitution for or complementary to pipe lines. A pipe line, for example, runs to Batum from the Baku oilfields, but distribution in central and northern Russia is made by rail. In Rumania, oil is piped to Black Sea and Danube ports for pumping on to ships; but travels also by rail through Hungary to Central Europe.

Tank cars comprise stoutly-made steel cylinders provided with internal baffle-plates to prevent the surging of oil in transit. They are filled at the refinery from mains beside the line, and can discharge through pipes direct into tank-lorries. A manhole at the top gives access to the interior.

(*f*) *Tankers and Barges*.—The former are sea-going vessels and the latter are used on the smaller waterways; thus the Germans employ all available oil-barges in order to utilize the Danube route to the greatest possible degree, while oil is delivered to Allied ports in tankers from America and the Persian Gulf.

3. Methods of Demolition.

Any demolition scheme will depend upon whether the installation is in hostile or friendly hands, upon the time available and the scale of destruction intended. The denial schemes in the Dutch East Indies, for instance, were prepared in great detail by experts some time before the Japanese invasion; their effectiveness would depend upon the period elapsing between the orders to demolish and the arrival of the enemy. They were executed with the assistance of technical employees. A raid carried out by hostile forces would, on the other hand, lack the careful preparation and long hours of work required for full-scale destruction. In the case of large installations, it will be seen that only a very thoroughly executed demolition scheme will have more than a negligible effect upon oil output.

Pressure Wells.—If the well can be plugged with cement, it will be quicker to sink a new one than try to clear the old. Before the cement can be introduced, however, it is necessary to damp down the pressure. This is done by pumping liquid mud into the well, a process employed in civil practice. When the pressure has been overcome, cement can be poured in through the pipes previously used for the mud. An important consideration, of course, is the quantity of cement needed to form an effective plug in a well several thousand feet deep.

Where time will not allow of the above deliberate operation, it is possible to open up the well and allow it to "flow wild," either by manipulating the valves of the "Christmas tree" or by breaking into the top of the tubing with an explosive charge. If a large number of wells is thus opened up, it will be difficult for anyone to cap them again before a great quantity of oil has been lost; moreover, permanent damage may be caused by loss of pressure and possibly in disturbance of the oil-bearing strata. Consideration must be given to the desirability of igniting the escaping oil. From the point of view of the demolition parties, a large number of burning wells is preferable to an area flooded with a mixture of air and inflammable gas, except in so far as heat or flame might restrict their operations. Should it be desired to ignite the oil, it must be remembered that the opening of the wells with cutting charges is unlikely to cause ignition; in fact, it is common practice to extinguish burning wells by the blast from an explosion. It would be necessary to employ an ignition device which would not be disturbed by the opening-up of the well, such as the firing of a signal cartridge from a safe distance. It may be accepted that the escaping gas and oil will sooner or later catch fire owing to the discharge of firearms or the striking of a spark in the neighbourhood. Where oilfields contain several hundred pressure wells, their hasty demolition will obviously be attended by considerable risk.

Pumping and Gas-Lift Wells.—Cementing here presents fewer difficulties, since mud-pumping is unnecessary. An alternative is to lift the tubing by means of the derrick and winding cable, and allow it to drop free into the well; the effect on a tube several thousand feet long is remarkable. A hastier method is to cut the tubing with a small charge at the top, so that it falls to the bottom of the well.

Engines and Electrical Gear.—It may be said at the outset that schemes based on the self-destruction of plant by overspeeding, under-lubrication, short-circuiting or overloading of electrical plant and similar means, although attractive, are unreliable. Modern plant is almost invariably fitted with protective devices designed to guard against such eventualities, and unless these devices are located and put out of action before destruction is attempted, little damage other than a temporary shut-down is likely to occur.

For hasty demolition, considerable damage may be caused by a sledge hammer used intelligently, suitable places for attack being, in the case of Diesel engines, the fuel pumps, injectors and governor gear (if accessible).

The commutators and brush gear of D.C. motors and generators, including the exciters of alternators or synchronous motors, are easily wrecked by the same means, resulting in a ruined armature. The end turns of the stator windings of A.C. machines may be similarly attacked, or spikes or long nails may be embedded in the windings.

Switchboard instruments, relays, and light switchgear are particularly vulnerable, whilst considerable inconvenience may be caused by breaking the porcelain insulating bushings on power transformers and high tension switchgear. (In parenthesis, if the equipment is live, the damage may be mutual!)

Cast iron, it should be remembered, is a brittle substance, and the valves on pipe lines may prove an easier point of attack than the piping itself, which is probably steel. Cast iron pump casings are easily wrecked.

If explosives are used, engine, generator and pump bearings should be attacked; a small charge on them will probably distort the shafts beyond repair, even if the shafts themselves are inaccessible.

Charges in electrical machines should be wedged between rotor and stator, and will do considerable damage.

Transformer tanks may be holed with explosive, and a second charge fired against the windings.

Skilfully directed small-arms, or better still anti-tank rifle or gun fire, will cause severe damage, particularly to cylinder castings, alternator windings, H.T. switchgear, and transformers.

The use of oxy-acetylene cutting equipment should not be forgotten for such work as felling structures supported on steel stanchions, and cutting the shafts of machines. It is not suitable for attacking cast iron or non-ferrous metals.

Care should be taken to destroy all the components of one type, including any spares, *e.g.*, Diesel engine fuel pumps, to avoid the possibility of cannibalization.

If time is limited, priority should be given (*a*) to " key " items of equipment and (*b*) to those portions of plant which owing to their design or workmanship cannot be improvised or made up locally, *e.g.*, fuel injection pumps and precision apparatus generally. The wrecking of overhead cranes and other lifting tackle adds materially to the difficulty of repair of heavy plant.

When possible, an E. & M. Officer or mechanist should accompany the wrecking party, to advise on suitable objects for attack.

Miscellaneous Material Required on Oilfields.—Seeing that the destruction of wells will only deprive the enemy of oil until such time as he has been able to re-drill, it is important to remove any tools or material which would assist him in this operation. Most essential are steel wire cable, boring tools, casing and tubing ; most of these are made in the United States, and their provision would add to the industrial burden of the Axis Powers. Their destruction in large quantities, however, is no easy matter, and if sufficient transport were available it would probably be more effective to carry them to a safe place or dump them in deep water. " Booby traps " may with profit be concealed among them.

Pipe Lines.—The pipes are usually buried in the ground, and damage at any point is easily discovered and repaired. Sabotage of this nature has been carried on from time to time by Arab bands on the Kirkuk–Haifa pipe, but has never had a serious effect. The most vulnerable points on a pipe line are the pumping stations, and the destruction of these would stop the delivery of oil until the plant had been repaired or replaced. The demolition of the pumps, engines or motors can be effected by the means suggested in the case of pumping and gas-lift wells.

Refinery Furnaces.—The parts most difficult to replace are the steel pipes through which the oil is passed while being heated, as these are of high-class material and manufacture. Owing to the large number of lengths of this piping in a furnace, the most effective way of dealing with them is considered to be an explosive charge which will throw out steel fragments to penetrate them in many places. If the charge be great enough it will also destroy the walls of the furnace by concussion. A suitable agent would be an aircraft bomb specially adapted to be fired electrically, or a charge packed in a container which is surrounded by a quantity of steel fragments in a second container.

Closed Steel Vessels.—A number of these is found in every refinery, being used in the form of " stills " (for heating and evaporating oil), in the cracking plant and for various chemical treatments. Owing to their stout construction and to the fact that they are not very difficult to replace, it is doubtful whether it is worth spending much time or material on their demolition. Calculation shows that concussion charges to burst them are generally unduly large, and the effect of cutting charges is small. If it be considered worth while to attack these vessels, however, charges will be most effective where pipes enter or leave the vessels.

Fractionating Columns.—These are probably the most important single items in a refinery, but their hasty demolition presents great difficulty. The columns are of thick steel designed to resist temperature and pressure, and covered with a heavy layer of lagging. Concussion charges would need to be disproportionately great, and would probably be impeded by the baffle effect of the " bubble trays," while the effects of cutting would not be hard to repair. An indication of the toughness of these towers is given by a known case involving the collapse of the brickwork on which one of them stood. The heavy steel vessel fell at full length on hard ground and was not itself damaged in any way.

If time allow, and the plant be still functioning, it would be possible to make the necessary pipe connections so that cold water would be injected into the column. The effect would be the sudden production of steam caused by the high temperature in the column, and the probability of its bursting in consequence.

Electrical System.—Most refineries depend upon electricity to a greater or less extent, and apart from wrecking the power station (which is itself a major operation) much damage can be done by smashing up the instruments and switch-gear and by destroying the transformers. A transformer can be put out of action by allowing it to function after draining its oil, or by breaking it up with explosives.

Pumps in Refineries.—If these cannot function, the circulation of oil through the refinery will of necessity cease. They and their engines should therefore be treated as suggested for oilfields and pipe line stations.

Destruction of Refineries by Fire.—An effective method of destroying a refinery is by flooding the whole place with oil and setting fire to it. When once started, it will be impossible to extinguish before great damage has been done, and the heat engendered by a fire on this scale will in many cases produce results superior to those of explosions.

A rapid method is to open the drain-cocks on the outflow of all pumps and to let them pump oil over the ground. The oil should be ignited at as many points as possible. The effect will be increased by making the necessary connections to admit oil to the fire mains and opening hydrants and drain cocks, but this will require several days' preparation.

If these means are adopted, it is obvious that no previous demolition work can be carried out on the pumps or electrical system.

Storage Tanks.—The destruction of "tank farms" has a two-fold effect; it deprives the enemy of a limited quantity of oil, but a more important result is the loss of storage capacity and the steel plates required for its replacement.

Consideration has been given to the possibility of demolishing tanks by exploding the mixture of air and gas inside them. While this is impracticable in the case of the heavier oils, it is only possible with the volatile products when the mixture happens to be correctly proportioned, and floating roofs make it quite impossible. Concussion charges are unduly extravagant.

Interesting data were gathered by one of the writers from the effects of air raids at Shanghai and at Haifa. When a tank was penetrated by bomb splinters, the contents leaked out and sometimes ignited. Where the oil failed to ignite, little harm was done and the tank could easily be patched; but when it caught fire the tank eventually collapsed and became irreparable. Furthermore it was found that a tank might burn without necessarily endangering another close beside it. The likelihood of ignition is of course proportional to the volatility of the product concerned.

The most reliable method is to let the oil out of the tank into the enclosed space surrounding it, and then to ignite it. This may be done by opening a valve or by blowing a hole in the side. The subsequent ignition presents difficulties varying inversely as the volatility; motor spirits and kerosene will burn easily, but the heavier oils must have their surfaces previously raised to flash-point. The writer assisted at some interesting experiments in this connection. An attempt was made to ignite a pool of furnace oil by setting off an incendiary bomb immersed in it, but the case of the bomb was so cooled by the oil that the bubbles of gas produced by the incendiary filling bubbled harmlessly to the surface. No greater success was obtained by suspending the bomb just above the surface of the pool. At length a basket filled with petrol-soaked rags was ignited and thrown upon the oil; a film of burning petrol quickly spread over the heavier product and in a few seconds it burst into flames. It is therefore suggested that, when it is desired to destroy a number of tanks, they should first be emptied into the bunded enclosures and the oil fired by some such method as described; if they cannot all be fired simultaneously, the party should take the precaution of working up wind.

A variant of the above would be to fire incendiary or tracer bullets into the tanks, but this is an uncertain method except in the case of light petroleum fractions. Where oil is stored underground, and sufficient explosive is not available for a charge to destroy the reservoir, the demolition party should concentrate on the mechanism by which the oil is extracted for conveyance elsewhere.

Means of Transportation.—Even if an enemy is in possession of intact oilfields and refineries, they are useless to him unless he can carry the products to where they are required. The Rumanian oil potential, for instance, is in the neighbourhood of 6,000,000 tons a year, whereas the capacity of the communications at the Germans' disposal is believed to be not more than 3,000,000 tons. Thus it will be seen that the communications are a more important objective than the oil installations, unless over 50 per cent. of the Rumanian oil potential can be destroyed. It is also probable that the gravest problem facing the enemy on capturing a Russian oilfield would not be the repair of the wrecked plant, but the conveyance of the oil to other parts of Europe. Japan will doubtless be able to restore to some extent the oil production of the East Indies, but this will be valueless to her without safe passage for her shipping.

Railway tank cars are specialized vehicles, the replacement of which presents greater difficulties than with other rolling-stock. As already pointed out, peculiarities of their construction include a manhole at the top and internal baffle-plates to prevent surging during transit.

Tankers and barges are even more valuable, as witness the efforts made by Germany to sink the tankers bringing oil across the Atlantic. Their removal or scuttling would be a serious handicap to any oil supply which depends on water transport.

Necessity for Careful Planning.—The above brief sketch demonstrates that the demolition of oil installations, owing to the risk of fire and explosions supplementary to the effects of placed charges, is not to be taken in hand " unadvisedly, lightly or wantonly," but with more than ordinary preparation and planning.

On the higher level, it must be calculated whether the plant to be attacked be of sufficient productivity or importance to justify the cost of the operation. A decision must then be made as to the parts of the installation to be attacked. The detailed plan must lay down to what extent the destruction can be carried out by technical means, and to what extent by explosives. Owing to the large number of wells in an oilfield, and the scattered nature and variety of plant in a refinery, it is clear that many small parties will be employed on the work, and careful co-ordination is required to ensure that the operations of one party do not endanger or hamper another. The programme must make certain that machinery required to assist the destruction (*e.g.* pumps, engines) is not put out of action until its task is accomplished. Where oil is to be fired, the movements of the parties and the priority of firing must be co-ordinated with the lay-out of the installation and the direction of the wind.

A FIELD COMPANY IN PERSIA AND IRAQ.

By THE LATE MAJOR H. A. H. RADCLIFFE-SMITH, R.E.

IN the train we sat back and enjoyed being in a position where we could do nothing. It was cool as we ran through Central India on the way to Bombay. What a contrast to the previous afternoon; memories came flowing back; standing in the sun—the inspection—how filthy the boys were, how badly their clothes fitted, and how young they looked—the bands playing and the men cheering—how hot it was—handing over Barracks, measuring the wicks of the hurricane *battis*, counting the keys—saying good-bye, would it never end!

The train stopped near Bombay, and the serjeant handed me a package. It contained orders to the effect that I was O.C. Ship, and a Court-Martial Warrant giving powers equivalent to a District Commander.

We had read "Procedure for troops embarking at short notice," we had even practised it, and got out of the train prepared to form a chain of rifles and carry out one of these evolutions which, though simple in practice, are made impossible in print. It was no longer done, so "Movement Control" told us, but having learnt to form a chain and to stack respirators on the left and tin hats on the right, it was confusing and demoralizing to walk on board just as one was. However we consoled ourselves with free tea from the excellent mobile canteen provided by the Bombay Rotary Society.

The voyage was without incident. We solved the cookhouse problem with the aid of good will, bad weather, and an excellent Quartermaster. One cookhouse for the Mussulmans, and one for the Hindus and Sikhs. For the first four days the weather was rough, and no one wanted to eat, the fifth day was fine and in the stampede one cook was nearly drowned in a cauldron of *dal*. We boxed, 10 per cent. conscripted entry from all Units, a minimum of skill and a maximum of enthusiasm, the only casualties were one man bitten in the leg, and one case of concussion. The latter was caused by a conquering Sepoy who, having knocked down his opponent, leapt upon him and seizing him by the ears banged his head upon the floor.

BASRA.

Basra was what we expected. The day we arrived and the next two days the thermometer hit 125°. All the troops, excluding the unloading parties, were marched off, and my Company, to their joy and everlasting gratitude, found transport waiting for them, which had been provided by another Field Company, which had discovered that we were arriving. We went into camp, and proceeded to count stores and made ourselves comfortable until such time as our M.T. should be unloaded. Our vehicles were on a freighter, which had left Bombay after, and arrived before us, and now lay at anchor, supervised by the Company 2nd-in-Command, clad in a beautiful blue dressing gown, and indicating to the world at large that he was feeling the heat.

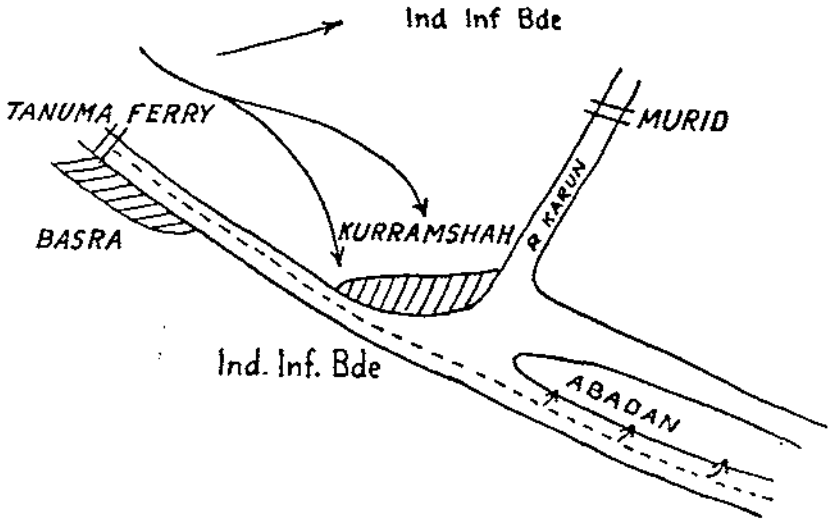
To our delight we found ourselves attached to the Brigade which was standing by in case there should be trouble with Persia, and for three weeks we practised our roles, as we visualized them. We worked from 05.00 hours till 13.00 hours and had no cases of heat exhaustion or heat stroke. Other Units which did not work such long hours did not keep nearly so fit.

On the 23rd August the situation became interesting, and the Company took up its War Stations: One Section under Command — Inf. Bde. for the attack on Abadan Island. One Section under Command — R. Mahratta L.I. for the assault on Kurramshah. The remainder, with under Command one Bridging Section at Tanuma prepared to make a light ferry over the River Karun at Murid, a place some ten miles upstream from the junction of that river with the Shatt al Arab.

ATTACK ON ABADAN.

The attack on Abadan was carried out from a motley collection of boats, ranging from small river steamers to motor launches. They were loaded up over-night at the R.A.F. wharf in Basra and stole down river under cover of darkness. Some of them grounded on the way but the plan went according to schedule, the enemy were taken by surprise, and the operation was overwhelmingly successful. We had been warned that we might expect barriers of unclimbable fencing, of the type found all over India round railway stations. The primary role of the Sapper detachments, of which there were four, was to make breaches in this fencing. Accordingly we had carried out experiments with portable demolition charges and evolved a tin container carrying two slabs of gun-cotton. This could be hooked over the fencing and secured with a strap in about ten seconds. Owing to shortage of space in the boats each party was limited to nine men. These were organized as shown in Appendix A.

Between them these parties had to break open eleven gates; on one only it was necessary to use explosives, for the remainder, sledge hammers, crowbars and picks sufficed. Apart from this trifling assistance, the Section under Command was required to blow up a house in which a machine-gun nest was located. With the aid of a Platoon of Infantry, a Sapper Subaltern and his few men managed to get into the ground floor. The house, however, was built on modern principles, reinforced concrete, air conditioning and all modern conveniences. The explosives in hand were not sufficient to effect complete demolition, and the R.A. had to be called in to shell the building. When all was over bar the shouting the Section gathered itself from the four corners of the Island. Some of the detachments had been well looked after, others had not. So small are these detachments, and so often are they commanded by junior N.C.O.'s, that their welfare is often neglected by the Unit they are helping.



ATTACK ON KURRAMSHAH.

The attack on Kurramshah was carried out by an Infantry Brigade.

The plan in general was for the Mahrattas to make a wide sweeping movement and to come in on the north of the town; while the Gurkhas came in further west. The two forces thus combined in a pincer movement. One section Sappers and Miners was under Command of the Mahrattas, its role being to breach or bridge any obstacles met with. The force was completely mechanized, or lorry borne, and the success of the operation depended largely upon there being no delay. From intelligence received it was anticipated that one or two small ditches or anti-tank obstacles might be met with; accordingly we got together a bridging train consisting of two 15 ft. span bridges and much *chattai* matting, sand bags, etc., with which it was intended to fill up small gaps. For three weeks the operation was practised and finally it was decided that the Sapper Section should move in two echelons, one immediately behind the Cavalry screen and one further back. After several practices the time from meeting the obstacle to the first vehicle to cross was 15 minutes: Two minutes for reconnaissance, two for getting the lorries up; nine for getting the bridges across and two spare. To our great regret the *nalas* were dry, the anti-tank obstacles non-existent and there was really nothing to do.

THE MURID FERRY.

The remainder of the Company with one Bridging Section under Command was concentrated on the north bank of the Shatt al Arab. The Bridging Section had no standard equipment. We had, however, extemporized by fitting up the folding boat trailers with *bellums*. The *bellum* is a boat anything from 30 to 40 feet long. It is very commonly used on the great rivers of Iraq, and can be driven either by man power or by sail; when three are connected together and boarded over, a serviceable raft, capable of taking three tons, is produced. "The Circus," as this odd collection of Units and vehicles was called, was ordered to proceed behind the attacking force in splendid isolation.

We were a little apprehensive of our safety, having no one who had navigated an M.T. column in the open desert. We had, however, a total of seven L.M.G.'s and about 250 rifles which, together with 24 anti-tank mines salvaged from a recent demonstration, formed our defensive armament. After 48 hours of false alarms we received a welcome message which put the operation in motion. At 04.00 hours we moved off, five columns, each of twelve vehicles, at 80-yard intervals. We did not lose our way and reached the rendezvous an hour before schedule, where we learned that the battle was going according to plan; though the dense columns of smoke on the horizon led one to imagine oil fires in Abadan.

After staying with Bde. H.Q. an hour we were ordered to move to Murid, a point on the River Karun about ten miles from where it flows into the Shatt al Arab. Here we were to make a light ferry in support of the assault crossing. The main task of ferrying across the river was going to be done by the big Basra ferry which was being towed down the Shatt for that purpose. We arrived at Murid after crossing the Desert well in the rear of the Persian army, and found an Inf. Company ready to assault but without any enemy to deal with. With our improvised gear little could be done. Bumping across the Desert had been too much for the *bellums*, and they sank on being put into the water. However, we did construct a raft from the few folding boats available and awaited the arrival of those who might have to use it. During the night we laboured on fitting a captured barge, so that, if required, it could take M.T. We also put up the usual water point in anticipation of the arrival of thirsty men.

It was our invariable experience that these water points were required long before any medical officer was available for testing the water. Fortunately the Horrocks Test is extremely simple and the L/Naiks in charge of the water points soon learnt to carry out the necessary sterilization. We found it necessary to equip two 15-cwt. trucks as water-pump lorries. Each carried a complete pumping set and W/S gear capable of watering a Bde. Each had its own Horrocks set, and half a cwt. of chlorinating powder. It was managed by the crew of three, one of whom was a L/Naik engine artificer and both the others were trained to drive both the pump and the truck. Each detachment had its own cooking gear, its own tent, and three days' reserve of rations. It was found possible for these detachments to deliver water within twenty minutes of arriving at the water point. Water-tank lorries were filled direct from the source, and the necessary amount of chlorine was put directly into the tank; this, in its journey, got sufficiently well shaken up. Water for those without lorries was chlorinated in a 1,500 gallon tank.

Day 2.—On the morning of Day 2 the Brigadier arrived, with the Bde. hot on his heels. They immediately took possession of the tug and barge on which we had laboured painfully. Close behind them came S.S. *Tanuma*, the ferry which plied across the Shatt al Arab from Ashar to Tanuma. She normally consisted of four flat-topped barges lashed together; this made a good platform for M.T. and was propelled across the Shatt by a barge. The loading was supervised by a Movement Control officer who had devised an ingenious drill, whereby the whole float could be loaded chock-a-block with up to 37 vehicles. On the outbreak of operations the S.S. *Tanuma*, complete with improvised landing stages, sailed down the Shatt and up the Karun to Murid, where she established herself and ferried a Bde. across the Karun river. The preparation of S.S. *Tamuna* and her establishment as a ferry at Murid was done by the other Fd. Coy., an outstanding achievement which received a special mention.

Disturbed by this activity the enemy, who had so far remained dormant, woke to life, and having made his gesture was quickly suppressed. The bridgehead and ferry were established and the crossing began.

By the evening the position was roughly as follows :—

One Inf. Bde. having made a wide turning movement were working towards Ahwaz; another Inf. Bde. having taken Kurramshah had established a bridgehead across the River Karun, and was in the process of crossing over; a third Inf. Bde. having assaulted and captured Abadan were engaged in mopping up operations.

Day 3.—Day 3 was uneventful except for chasing our rations. To supplement these there was an abundant supply of meat on hoof. Hunting gazelle from a lorry was one of the high lights of the Campaign ; they could either be stalked and shot sitting, or be taken from a lorry on the run. They could do fifty and turn very sharply, so it was most necessary to find a driver whose reactions were under good control. Moving across the Desert at fifty miles per hour standing in a 15-cwt. truck and taking pot shots at a gazelle is an experience never to be forgotten.

Day 4.—In the evening of Day 3 we were joined by the Section which had been on Abadan. The next day Div. H.Q. with Div. Troops and one Inf. Bde. were ordered to move to the *R* in Karun, a map reference which was to become familiar to the Coy. We were placed in a bad position near the tail of the column, and for three hours followed our own route, striking well out into the Desert, where the going was good and we could move on a broad front. On striking back to the road to make contact we came on a scene of considerable confusion ; 32 lorries, most of them three-tonners, and at least two L.A.D. lorries, were bogged in a drift of sand; this was an excellent example of lack of traffic control. Had the drivers of the first two vehicles used their direction arrows, the remainder of the column would have been diverted round the bad patch. There was no one else who could do it, so we unditched the majority and brought them in to the *R* in Karun.

Four vehicles, however, could not be shifted and had to spend the night in the Desert guarded by a section which lived on gazelle and fish blown out of the river. It had been a hard day chasing up and down the line of ditched lorries scattered over forty miles. Operations were still in progress, the attitude of the local Arabs was unknown, and one was torn between a need to guard the vehicles and not to over-disperse the men. Communications there were none ; a Field Company, so frequently out in the blue, has no signals; we were fortunate, however, in making contact with a tug which sailed up the Karun. The Naval Officer Commanding told us that he had intercepted a message which indicated that an armistice had been signed, so we decided to guard the immovable vehicles and left a sub-section of Sappers with each.

Day 5.—Day 5 we spent at the *R* in Karun where we rested from our labours while derelicts were brought in. We fed royally, the local village provided eggs and melons, gazelle were found in the Desert, and the river yielded up fish in abundance. That evening we had a fishing parade. There was a jetty jutting out into the river on which we stationed about fifty swimmers, while three parties rowed about in the stream. We threw in three or four slabs of gun-cotton from the end of the pier and picked up a truck-load of fish. It was great fun and tremendous exercise, swimming after and catching the half-dead fish.

Not till after we reached Ahwaz did we learn that the River Karun was full of sharks.

When we got to Ahwaz the war had been won and we settled down in camp for a week, while we overhauled our M.T., established water points, and did a number of reconnaissances. During this spell we were visited by the Force Commander, who walked round and talked to the sepoys in their own language about themselves, and their letters, their families and their own personal needs, which put us in our right minds after the strain and recrimination which is a part of War.

THE DIZFUL ROAD.

Like a bolt from the blue we got a new job; it was 18.00 hours when we were told to go and open up a road from Ahwaz to Dizful *via* Shush, as the Kumaon Rifles would shortly be passing through. We went as quickly as we could, which was next morning. A Field Company near H.Q. is the most unhappy of units, it is imposed upon to build shelters, dig latrines, and make cook houses. It may represent that it never had time to train itself in bomb disposal, in mine laying and removal, or in watermanship; such pleas are in vain if it is unfortunate enough to be within range of a formation which can get at it.

Early next morning I sallied forth with a Section, intending to go through to Dizful and back to Shush. The Coy. 2nd-in-Command was to bring the main body of the Coy. up to Shush, where he was to meet us. One Section was to stay behind collecting petrol, rations, and bridging materials with which it was to come up as quickly as possible. The " Road " was a dotted line on the map supplemented by a somewhat inaccurate reconnaissance report; however, the going was good till we got to Shush which was reached by lunch time. At Shush we were confronted by a ford 150 feet wide and 2 ft. 6 in. deep. The sand-bank crossed the river like a horseshoe, it was a bare twelve foot wide and somewhat tricky to negotiate. We took the simple precaution of removing our fan-belts and passed through without misfortune.

There were three more fords between Shush and Dizful, so by the time we returned to Shush that evening our drivers had thoroughly learned how to remove and replace the fan-belt of the Chev.

All our trucks were Chevs., other convoys which followed us were not so lucky, they had some Fords. The Ford is not nearly so good as the Chev. through water, its fan cannot be disconnected because the belt also drives accessories other than the fan; and as the distributor is placed low down in front of the engine it is easily flooded and most difficult to clean out. In fact the latter operation involves standing with the pit of one's stomach on a boiling radiator, with one's head in close proximity to a scorching cylinder block.

The main part of the Coy. got over the big ford without difficulty, and made a striking picture winding their way across the sandbank in the darkness with headlights full on and almost level with the water. Half a mile further on we had our first misfortune of the day; a lorry near the end of the convoy went through a culvert; it was a silly little culvert and no damage was done, but it happened to be at the gate of the local Persian Barracks; the British mechanized army which had so recently defeated the might of Persia had been brought to naught by a dirty little irrigation channel, which watered the garden of a Persian platoon.

The job consisted of strengthening twelve culverts with spans of from four to eight feet, of making three other bridges of fifteen feet span, one of 152 ft. span, and one of 64 ft. span. In addition to this we had to mark the roadway. The stores available were seven three-ton lorry loads of R.S.J.'s and sleepers, which we had brought with us all the way from Basra. Reconnaissances revealed a satisfactory dump of stores at Dizful 20 miles away, and a large dump of sleepers at Shush railway station. We decided that everything could be done with the stores available and sent in our indent for dog spikes and cross-cut saws.

The day after our arrival in Shush, one Section went back along the road to mark it out, and to strengthen the culverts on that particular stretch. The method of marking out was to drop sub-sections at the points where definition was required. These then built a double line of *burjis* (cairns) until points were reached where the track became distinct, they then leap-frogged the remainder of the section and carried on at other indistinct points. In this manner we covered 40 miles by lunch time, building some eight miles of *burgis* at various danger points.

As we were resting from our labours we were met by the section which was coming up with the bridging material. It was decided that this should proceed to Shush, dropping at each culvert stores required for repair. The section which had done the road making was to spend the night in the Desert and work its way back to Shush making good the culverts as it went, which it did the next day.

In making up the long bridges a great number of log trestles were required, which involved the cutting up of a vast amount of timber. The only means at our disposal were four Unit equipment cross-cut saws, worked by hand. After building one bridge by this tedious method we made up a simple attachment whereby the saws were coupled up to the wheels of lorries. This was most effective, the only limit to the speed of cutting being the fear of melting the saw.

The whole job was finished comfortably in a week. With an unmechanized Coy. the work could not have been done in less than a month. Such is the power that M.T. gives of concentrating the men and tools required at the right point that it is quite simple for a Field Company to work on a hundred miles of road. If, as has been mentioned before, a few wireless sets were available the position would be better still.

Having nothing further to do we sat down in a camp where our abiding discomforts were mosquitoes and snakes. The former came out at night; they arrived punctually to the minute for their evening meal and woe betide anyone who was found in *negligé*. After this onset, lasting about an hour, they left us until about two a.m. when they would return for another snack before calling it a day. The snakes were with us always, brown, black and green snakes, long and short snakes, thick and thin snakes. We killed 70 of them in three weeks.

For two weeks after completing our job we remained at Shush and got down to intensive M.T. training, which was our habit whenever we settled down and had a spare day. By the end of six months overseas, using odd days between jobs of work, we trained 50 per cent. of the Unit to drive, 100 per cent. of the Unit to do M.T. maintenance and some 10 per cent. to do running repairs. Our maintenance routine was a stables parade either first thing in the morning or last thing at night; at the same time all the equipment carried on each vehicle was overhauled and all weapons cleaned. This was the joint responsibility of all persons who travelled in that vehicle.

Move to "X."

When our fortnight was up we were ordered to move to "X". We sent off an advance party to pick up our extra clothing and to make good our losses of the Campaign, and followed in our own time. From Basra to Bagdad we were obliged to move with the H.Q. of a formation which had just arrived overseas. We had been in the country two months and had developed a fine scorn for anything "raw"; this was aggravated by being kept waiting on the starting point two hours the first day and one and a half hours the second, after which we got permission to lead the column. We left Camp daily an hour before dawn, when the cold was intense, in lorries which had no windscreens. We donned our battle dress unceremoniously, and, there being no time for fitting, some of the misfits were extremely comic.

We found that for comfort it was necessary to get into Camp two hours before dark; this gave time for M.T. maintenance, cooking and digging slit trenches which we always did as a training routine. It is also very necessary to develop a drill for going into and getting out of Camp. If this is done, a colour party is not necessary, traffic control is automatic, and everyone knows where everyone else is. Having no other means we began to develop a system of Morse signals using our horns, but had to abandon the working out when we became involved in " X " 's defences.

On arrival from Bagdad we were handed movement orders instructing us to proceed to Kirkuk. I happened to turn the sheet over, and found written on the other side, " Pay no attention to this, you will get another in an hour's time." Sure enough we received an order telling us to go to " X "; this was joyfully received as all the old *quai hais* had told us, " Everywhere in Iraq is b——y but " X " is the least b——y." We were favourably impressed by our reception, we were met, made to feel at home, and cared for, by a Bde. under whose Command we were placed. The contrast with other Coys. who were not " under Command " was most striking. We got twice as many tents and a lot of amenities which others had not even heard of. As soon as we made ourselves comfortable we got down to M.T. training which, for two weeks, we combined with making a road. Thereafter, as work on the defences began in real earnest, all thought of training had to be abandoned.

We worked on a mass production system. The steel work was bent at the Base, sent up in bundles for each particular emplacement, re-sorted at the Advance Engineer Park and sent out to the area concerned where it had invariably to be sorted again. Pioneers also worked on mass production lines, they had gangs for laying floor steel, pouring the floor concrete, placing the shuttering, placing the wall steel, etc., etc.

The " assembly " line moved from right to left and we were on the right, with the result that we got less time and more inspections than the remainder, and were kept very busy watching 6,500 men who were working in our area. When things were at their height the author was recalled to India, thus ending the busiest, fullest and most enjoyable 6 months of his life.

APPENDIX A.

Organization of demolition party.

Men with made-up charges	4
Men with crowbars	2
Man with sledge hammer	1
Man with pick	1
Commander with lashing	1
	9

All men carried wire cutters with rifles.

THE ROYAL ENGINEERS AND THE ROYAL TANK CORPS.

II.—AFTER THE WAR OF 1914–1918.

IN a previous article, published in the September, 1942, number of *The Royal Engineers Journal*, mention was made of the special Royal Engineer units which were formed before the end of the war to carry out all normal R.E. duties for the Tank Corps units in the field. During the war, the Tank Corps employed special tanks for such duties as the removal of barbed wire obstacles on a wide front, laying bridges under fire, and cable burying with a mole drainer. These are normal R.E. duties and the use of special tanks manned by Tank Corps crews hastily trained in these duties was disorganizing for the Tank Corps. Other arms of the services are relieved of these duties, such as bridging and the demolition of obstacles, by the Royal Engineers. It, therefore, became apparent that a special R.E. unit would be needed to carry out these duties for the Tank Corps, using their own specialist tanks. Trained sappers would, of course, be able to adapt themselves to these varying duties far more easily than the crews of fighting tanks, and a much higher state of efficiency would be obtained.

It was first necessary to obtain a suitable type of specialist tank which could carry out as many of these duties as possible. Professor Inglis had designed a tank for laying the 21-ft. bridge, but this tank did not lend itself to some of the other duties. A new design was, therefore, prepared and constructed at Christchurch and this became known as the R.E. tank. This tank and the feats which it could perform were described in the October number of *The R.E. Journal*, 1920. Briefly, the tank had a short stiff derrick in front actually worked by a hydraulic ram which was served by a Janney pump, and the tank could perform the following operations :—

(*a*) Carry and lay under fire a 21-ft. bridge to take tanks weighing 35 tons. The operation could be completed in less than a minute and without exposing anyone to fire.

(*b*) Tow a heavy steel roller weighing 2 tons from the end of the derrick, so that the roller was drawn along in front of the tracks of the tank. In this way it was found that a passage could be swept through a minefield, and the anti-tank mines which were detonated by the roller did not hurt either the roller or the tank or the tank crew.

(*c*) Push a heavy Inglis bridge which was mounted on idle tracks. In this way it was found possible under suitable conditions to bridge gaps up to 70 ft. to take 35-ton tanks and without exposing anyone to enemy fire. The bridge was pushed across the gap in less than a minute.

(*d*) In addition to the above, the tank could be used for all other specialist duties which had been evolved by the Tank Corps, such as clearing barbed wire obstacles with grapnels, etc. A further duty was evolved and tried out, viz., the demolition of a tank obstacle under fire by carrying the demolition charge at the end of a bowsprit fastened on the derrick of the tank and then holding the charge by this means on the obstacle while it was detonated electrically from inside the tank.

Most of this work was evolved at Christchurch just after the war and if the Armistice had not intervened there is little doubt that in 1919 we should have seen R.E. tank field companies equipped with these specialist tanks and attached for this work to Tank formations.

As it was, great changes took place after the end of the War. The role of the Army was changed from trench warfare to mobile operations. The heavy wartime tanks which had been designed for trench warfare became obsolete and there was, therefore, no use for R.E. tanks of this particular nature.

In the meantime, mechanization began to spread slowly in the Army, and some of this work, which had been started by the experimental bridging company to meet the requirements of the Tank Corps, spread to R.E. field units. The use of mechanical power for bridging and other purposes was developed. This was not, however, accompanied by the use of armour protection. The Royal Engineers' work that was initiated with the Tank Corps included the idea that R.E. personnel would often advance behind the same type of armour protection as that which was used by the tanks, so that they could assist them in R.E. duties in the forefront of the battle. With the development of more modern and faster tanks for mobile operations the necessity for this R.E. co-operation was less apparent. It seemed quite possible that, in future, certain R.E. personnel would accompany the Royal Tank Corps in armoured tanks or vehicles, so as to be ready to assist them in mobile operations with demolitions or bridging, etc., but although this question had been studied from time to time no clear-cut proposals were formulated.

After the war, the Tank Corps Training Centre was established at Bovington with Major-General Sir Hugh Elles as Commandant up to 1923, when he became the first Inspector of the Royal Tank Corps at the War Office.

It was now decided that the Ordnance Corps should take over tank repairs and the special Engineer officers in the Royal Tank Corps were abolished, though Lieut.-Colonel G. C. Gowlland, R.E., remained in charge of the workshops at Bovington until 1922. Some of the remaining officers who had been borne on the Royal Engineers list and who had served as tank engineers accepted transfer to the Royal Army Ordnance Corps or Royal Army Service Corps and some took regular commissions in the Royal Tank Corps.

In 1921 the Royal Tank Corps were equipped with the first post-war tank made by Messrs. Vickers, which was a far lighter and more mobile machine than the war tank. It was, however, still a large and expensive machine. On several occasions suggestions had been made that there would be many advantages in using a larger number of smaller machines than the Vickers tank for an attack on a defensive position. It was pointed out that anti-tank weapons were increasing in numbers and efficiency and that just as infantry had been forced to use dispersion in the attack to avoid machine-gun casualties, so the tanks would have to pursue similar tactics to avoid casualties from anti-tank weapons. In other words, the proposal was that it might be found better to attack a position with large numbers of small and comparatively inconspicuous machines rather than with smaller numbers of larger machines. As no official action had been taken on these proposals, Major G. le Q. Martel, R.E., designed and constructed with his own hands a small tank which could be driven comparatively easily by only one man, who could also fire a machine gun to the front or flanks. Demonstrations with this machine were given by Major Martel to representatives from the War Office and to the Staff College at Camberley. These raised considerable interest and it was then decided to take official action. It was agreed that two men would be better than one and a number of these machines were then built by Messrs. Morris Commercial to take two men with an armament of one light automatic. This action led Sir John Carden (then Mr. Carden) to revive a small type of unarmoured machine to which he had given some thought, and which had primarily been intended to carry machine guns up to the front. Major Martel had not the time to pursue the development of his own machine, which had been built privately, but he had many discussions with Carden, and the later models produced by Carden, which differed considerably from his first ideas, became very useful machines. This form of small machine eventually bifurcated into two types ; one type became the machine-gun carrier and the other the light tank.

In 1926 it was decided to form a mechanized force on Salisbury Plain. The striking portion of the force was a medium tank battalion, and this was supported by a brigade of field artillery and a machine-gun battalion carried in cross-country lorries. A number of the small machines referred to above were added as a reconnaissance unit. It was then decided that the 17th Field Company, commanded by Major G. le Q. Martel, R.E., should be mechanized and co-operate with this force. It will be seen that a large part of this force was unarmoured and the field company was to be unarmoured also. Much of the work of the 17th Field Company was the normal duty of a field company though entirely mechanized. Some attempts were made, however, to revive the ideas of the special R.E. units working with tanks, which had been tried during and immediately after the war. The necessity again became apparent for a short bridge of about 30-ft. span which could be laid under fire for the passage of tanks over small rivers or obstacles. A clever design was prepared by Major H. H. Bateman, R.E., but owing to various reasons, such as the uncertainty as regards the weights of future tanks, this design was not perpetuated. An improved type was eventually designed in 1936.

While the mechanized force was being formed, a great display of mechanical vehicles was given to the Dominion Premiers in the autumn of 1926, which heralded the formation of the mechanized force. The 17th Company was ordered to provide a display of passing tanks rapidly over river obstacles as part of this demonstration. In addition to the use of the normal pontoon equipment, three other methods were demonstrated. First of all, tanks were passed over a stream, which was 50 ft. wide and 5 ft. deep, by the use of light timber " stepping stones." By this method the first tank was passed across in just under one minute from the arrival of the sappers at the site. Next the tanks were passed over an improvised 60-ft. light box-girder bridge which was launched across the river and completed in 17 minutes. Lastly, the bridge designed by Bateman was placed across the river where it was about 28 ft. wide and tanks were passing over within two minutes. This bridging display occupied less than half-an-hour and showed that river obstacles would not necessarily be a serious handicap in future tank operations.

Many other devices and schemes were tried and some led to final adoption.

In 1928 the name of the mechanized force was changed to " Experimental Armoured Force " and it was intended to assume for the purpose of trials that the whole force was armoured. This, however, was ahead of practical possibilities, and the following year the force was disbanded. A little later it was revived in a different form as the Tank brigade. In this form the whole force was armoured except for the transport. No steps were, however, taken to introduce an armoured R.E. unit into this Tank brigade.

After the war, General Sir John Capper became Colonel Commandant of the Royal Tank Corps and later both General Sir Ernest Swinton and General Sir Hugh Elles became Colonels Commandant.

In 1934, Brigadier P. C. S. Hobart (late R.E.), who had joined the Royal Tank Corps after the war, became Inspector of the Royal Tank Corps at the War Office. In 1937 he was appointed to command the Tank brigade. Brigadier Hobart had been an ardent enthusiast for mechanized warfare from the start, and much of the progress made in establishing mechanized forces for mobile warfare was due to his initiative and drive. He became Director of Military Training in 1938 and was promoted Major-General, and towards the end of that year he was ordered to Egypt to form a mobile division in that command.

THE INDIAN DIVISION IN THE MATMATA MOUNTAINS.

Extract from Home News Bulletin, 9 p.m., 20th April, 1943.

(Published by the kind permission of the B.B.C.)

Godfrey Talbot told us this afternoon from Cairo one of the most stirring tales of this war. This was the situation :—On March the 27th the 4th Indian Division had cleared the southern gorges of the Matmata Mountains and had opened a line of supply for the New Zealanders. It then turned north. On the afternoon of the following day the Division came to the northern edge of the Matmata Mountains. Only a few miles away, but fifteen hundred feet below, the British and German armour was locked in battle at El Hamma, and the track in front of the division had been blown up. It was little more than a trail built into the walls of a narrow gorge, and it seemed then that the division would never go into action to strike its blow in the battle for Gabes.

Talbot describes the two men chiefly concerned, the Colonel Commanding the Divisional Engineers, and Major Jock Murray of the — Field Company of K.G.Vs.O. Bengal Sappers and Miners, standing at the top of the gorge. The Colonel says: " I can give you a couple of compressors if you can get them down there." And Murray replies: " I'll get them down somehow, sir, but I shall want a lot of men." There was a line of vehicles ten miles long halted at the top of the gorge, and a string of three-tonners carried a battalion of Ghurkas. The Ghurkas, the compressors and a bulldozer began to move gingerly down the winding trail. Almost inch by inch the machinery reached the first gap in the trail and the drills began to cut away the overhang.

Down into the bottom of the gorge the Ghurkas swarmed, they formed four human chains up the cliff side and swiftly began to pass up stones from the bottom of the ravine. The stones travelled from hand to hand until they reached the Indian Sappers at the base of the gap in the trail. Equally swiftly, the Sappers built the stones into a retaining wall. The bulldozer began to push tons of earth and rubble above into the hole behind the retaining wall. Before the eyes of the officers watching anxiously on the heights above, a new road grew. Once the first gap was bridged, the compressors, the bulldozer, the Sappers and the Ghurkas moved on down the gorge, behind the shoulder of the mountain which hid them from view. There they set to work again in the same fashion. Without halt or rest, save for an occasional brew of tea, and a bite of *chupatti*, they worked for eight hours. At the end of that time, the trail was restored, and the way to the plain was open. The new road must carry a Division, twelve thousand men and two thousand vehicles. From the gorge, the Colonel sent up the message to the General: " We are ready for the first traffic, sir." The head of the column began to move down. "Careful! Punjabis, keep close to the rock," called Major Murray. After the Punjabis, the Rajputana Rifles came through, slowly and cautiously. And after them, the guns—Bofors, 25-pounders and long mediums. This was tricky work, getting a towed gun round the corners. A few stones gave way, but at last the guns are out of sight. What's this? Tanks, impossible, but they too, managed to get a spider's way along the edge of nothingness, and so, bit by bit, throughout that afternoon the whole Indian Division found its way down through that gorge into a narrow valley at the bottom, where a road ran through a dried river bed. Soon the report came back that the advance guard had reached the open plain, the Ghurkas, still in the lead had overrun an Italian rearguard and taken a hundred prisoners; the road to Gabes was open—and that night Rommel began to get out. " Jolly good work, — and Murray," said the Divisional Commander. " Jolly good work, men," said the Colonel and Major Murray. The Corps Commander sent a special letter about it, everyone in the Eighth Army knew what a fine thing had been done, and the Indian Army Public Relations Branch decided to record a reconstruction of the scene for you, the listeners, to record it with all the noise and with the principal participants, the Colonel and Major Murray and some Sappers and Miners and some Ghurkas telling their stories in their own way. But the Indian Division was still in battle and, ten days later, while building a crossing for the anti-tank ditch in the battle of the Wadi Akarit, the Colonel and Major Murray were killed by the same shell. The crossing which they made enabled the Indian Division to penetrate into the hills behind Wadi Akarit, and to change the course of that battle. So, this is simply a straight story of a splendid feat of arms in the Matmata Mountains. It is also homage to two gallant men, and fine soldiers, whose memory remains green among those of the Indian Division who fought and worked beside them.

EQUATOR AND ECLIPTIC.

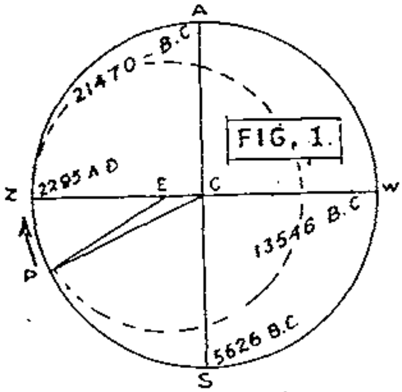
A Statement of the Drayson Problem up-to-date.

By LIEUT.-COLONEL T. C. SKINNER, F.R.MET.S., late R.E.

Note by the Publications Committee.

The Committee takes no responsibility for the contents of this article, but as some senior officers in the past were interested in Maj.-Gen. Drayson's theory they have agreed to publish this—so-to-speak—interim report at the request of those who are still carrying on that interest.

OLDER Members of the Corps will recall considerable correspondence in *The R.E. Journal*, around the end of the nineteenth century and beginning of the twentieth, concerning Drayson's claim to have discovered the true course of the pole of the earth's equator and axis as tracing a circle round a centre situate, not, as was supposed, at the pole of the ecliptic " E" (see Fig. 1), with a radius



of about 23½ degrees—continually decreasing—but at a point " C," 6 degrees away therefrom, in r.a. 18 hrs. and with a constant radius of 29°25′47″, the results of which discovery were far-reaching and of great importance.

There followed a lull, but despite discouragement of any investigation by the " orthodox " astronomers, adherents were never lacking to keep the question alive, among them Admiral Sir A. F. R. DeHorsey, K.C.B., A. H. Barley, Esq., an amateur astronomer, D. W. Horner, Esq., F.R.A.S., F.R.MET.S., Major. R. A. Marriott, D.S.O., Colonel J. B. Stracey Clitherow, C.B.E., and at least two distinguished members of the Corps, Maj.-Gen. Sir Wm. Salmond, K.C.B. and the Rt. Hon. Lord Sydenham of Combe, G.C.S.I., etc., F.R.S., both of whom helped in measure to hand on the torch before quitting the scene.

Since 1927, however, when errors in timing the solar eclipse of that year and locating its track afforded opportunity to expose afresh the consequences of neglect, things took a somewhat different turn, resulting in the forming of a team of workers of whom Lieut.-Colonel J. H. S. Murray, late R.E., Brigadier N. M. McLeod, D.S.O., M.C., late *A.D.C.*, late R.A., and the author, are active to-day. These with cordial co-operation of Prof. Lieut.-Colonel F. J. M. Stratton, D.S.O., M.A., F.R.A.S., etc. (Gen. Secretary, International Astronomical Union), of Cambridge Solar-physics Observatory, embarked on an unofficial investigation that has already produced definite results and is still proceeding, some particulars of which, it is thought will be of interest to the older members of the Corps, and to the younger men whose interest has been awakened in later years.

It is not proposed to give here any detailed description of Drayson's own research and its results; lack of space forbids. Readers are referred to his own works, chiefly *On the Motion of the Fixed Stars* (1874), and *Untrodden Ground in Astronomy and Geology* (1890), copies of which are available for reference in the Library of the British Museum. The Corps Library also has a copy of *Untrodden Ground*, and popular accounts are available in a recent article by Brigadier McLeod, in the *Journal of the Royal Artillery*, April, 1940, entitled *Climate and the Ecliptic Tilt*, and in a paper on *The Ice Age, its Astronomical Cause*, read before the Victoria Institute by the author in 1929, copies of which will be supplied gratis on request.

But it may be of interest to know how this investigation arose. Sir Wm. Salmond had suggested to the author the desirability of depositing a selection of Drayson's and other writings, to be brought forward every 25 or 50 years, under trust, to keep the matter alive. An introduction to Prof. Stratton by another brother officer, Maj.-Gen. E. R. Kenyon, C.B., C.M.G., led to his ready acceptance of the trust, but in modified form, he recommending that forecasts by Drayson's formulæ, in parallel with like series by an official calculator, be deposited in sealed envelopes, to be opened for comparison with the *Nautical Almanac* and *observed results*, at the appointed dates.

In his last-published work, *Untrodden Ground*, Drayson had recorded back-casts of polar distances of some 23 stars, from 1887 (Queen Victoria's jubilee year) to various dates, 50, 100, 150 years in the past, agreement of which with the recorded observations was seen to be correct. These Prof. Stratton accepted without question, but deeming that the acid test of a formula lay in forecasting, he selected twelve of the twenty-three stars and forecasts on the two formulæ from the same epoch, 1887, forward to 1930, 1933, 1936, 1940 and 1950, worked out by Col. Murray for the Drayson test, and by Dr. W. M. Smart, F.R.A.S., of Cambridge, for the "Orthodox," were duly deposited in his care.

It is necessary here to explain that prior to 1901 Drayson's simple triangulations, based on his discovery of the true centre of the polar motion, offered the only means of prediction for anything more than three or four years in advance, the *Nautical Almanac* being at that time compiled by winnowing out the best results from the harvests of many observations mainly at Greenwich. In 1896 innovation was made in recording in the *Almanac* determinations of the so-called *proper motions* of the stars, while in 1901, formulæ, drawn up by a distinguished American astronomer, Simon Newcomb, were adopted, enabling predictions of star positions to be made for considerable periods with much accuracy. Unlike the Drayson triangulations, however, which are based on the simple circular movement of the pole round a constant centre, Newcomb's formulæ are referred, in effect, to a complex movement of the pole round a moving pole of the ecliptic as centre* with adjustments at the circumference in respect of the proper motion assigned to each star. That they work so accurately is a tribute to the patience and skill of their inventor.

On these two formulæ, then, the star tests were arranged, though from the outset the Drayson team felt it necessary to make a proviso as under, which they embodied in the preamble to the 1930 test :—

"As to the relative advantage or disadvantage of either method, we feel we are not qualified to speak; but the point we desire to emphasize is that Drayson's formulæ, which are the direct expression of a circular movement of the pole of the heavens round the point C, six degrees away from the ecliptic pole, in r.a. 18 hours, need only *substantial agreement of average results* to demonstrate its truth in principle. It is not a question of which method gives sharper definition, but rather, does Drayson's method give enough definition to disclose a secular movement hitherto unrecognized or hitherto misinterpreted? Refinement of result can, obviously, only be looked for when, the principle recognized, its full effect is allowed for in the ephemeris from which the data for calculation are derived.

*See Section 9, page 136.

"Hence though we do not claim that effective processes in use to-day should necessarily be replaced by Drayson's formulæ, we do submit that his formulæ, which pointed to this unrecognized polar movement sixty years ago, point in the same direction to-day, and that recognition of the same will immediately supply the needed criterion of sidereal time and assist to remove many anomalies admittedly not understood in official circles though a source of perplexity to astronomers the world over.

"Further we desire it to be clearly understood that no challenge is here offered to the fact of 'proper motions' in their essence, though, when the real polar motion as defined by Drayson is recognized and allowed for, it may well be that some modification of the 'proper motions' now assigned, either in direction or extent, may be found necessary."

The accompanying polar diagram (Plate A) shows the 23 stars employed in *Untrodden Ground*, those shown thus O being the 12 selected for the tests. In the diagram the pole of the heavens, "P," will be seen to be moving in its precessional circle round "C," the pole of second rotation, towards 0/24 hours r.a., radius 29°25′47″. The dotted circle drawn round "E" as centre, radius at epoch 1887, 23° 27′ 14.22″, but decreasing, illustrates the path of the pole in the precession assigned to it by the Orthodox round the ecliptic pole as centre. Viewing the pole "P" as moving in the direction of 0/24 hours r.a., or away from the direction of 12 hours r.a., for purpose of definition we have referred to stars situate in these directions as *fore-and-aft* stars, those towards 6 hours and 18 hours being called *beam* stars. Thus γ Pegasi and α Aquarii (with β Leonis and α Virginis) we have styled *fore-and-aft* stars; others, as α Aurigae and γ Draconis, being "on the beam," so to speak, we have called *beam* stars; the remainder are referred to as *intermediate* stars.

Coming now to results:—The first series, the forecasts to 1930, were opened at Cambridge by Prof. Stratton and the author on June 10th, 1931, the results being as tabulated below, along with results of *observation* supplied by courtesy of the Astronomer Royal:—

Forecast—1887 to 1930=43 years.—(Polar distances)

Star.	*Naut. Alman.*	*Obsn.*	*Cambridge*	*Drayson.*
γ **Pegasi.**	**75° 12′ 19.62″**	**20.77″**	**19.64″**	**19.08″**
α Urs. Minor.	1° 4′ 17.43″	17.67″	17.40″	12.86″
α **Aurigae.**	**44° 4′ 16.28″**	**17.23″**	**16.30″**	**15.04″**
β **Leonis.**	**75° 2′ 11.74″**	**12.42″**	**11.70″**	**11.00″**
α Virginis.	100° 47′ 47.17″	47.27″	47.20″	48.48″
α Libræ.	105° 45′ 6.62″	6.96″	6.60″	5.59″
α Scorpii.	116° 16′ 41.00″	40.62″	41.00″	42.29″
β Draconis.	37° 38′ 50.70″	51.22″	50.70″	51.35″
γ **Draconis.**	**38° 30′ 12.62″**	**13.10″**	**12.60″**	**15.36″**
α Lyræ.	51° 16′ 56.83″	57.85″	56.80″	58.78″
α Cephei.	27° 42′ 41.17″	41.33″	41.20″	44.18″
α Aquarii.	90° 39′ 37.89″	38.70″	37.90″	38.19″

N.B.—It is understood that while *observation* cannot be relied on below 0.50″, a discrepancy of over 1.00″ would be viewed as unsatisfactory.

Analysing these it was seen that though there was little to choose between "Drayson" and "Cambridge" in respect of the leading "fore-and-aft" stars, in the case of some *beam* and *intermediate* stars the discrepancies were markedly in favour of "Cambridge," and results of the first test seemed discouraging. But, at a subsequent conference on June 11th, 1932, it having transpired that, through an unfortunate misunderstanding, the Cambridge forecast had not been referred to 1887 datum, but had started from some other epoch about 40 years later, with effect of placing the Drayson forecasts under a 40 years handicap, it was agreed to cancel the Cambridge series and recompute to 1933.0, 1936.0, 1940.0 and 1950.0 from 1887.0 as originally desired.

This, however, presented some difficulty in that *proper motions*, having been recorded first in the *N.A.* of 1896, Newcomb's formulæ were inapplicable to the *N.A.* of an earlier date; but by the good will of Prof. Stratton and able assistance of his colleague, H. E. Green, Esq., M.A., of Cambridge Observatory, the difficulty was overcome by starting from epoch 1896.0, with adjustments for proper motions back to 1887.0, from a table devised to cover the intervening years, based on the 1896 records, and this was agreed to on July 12th, 1932, as the best accommodation that could be made in the circumstances.

If it be asked why the Drayson tests could not have been post-dated to start from "scratch" at any convenient epoch, say 1930.0, there were four sufficient reasons for adhering to 1887: *First:* To carry Drayson's work forward in continuity without a break. *Second:* To secure the benefit of early and progressive results, for analysis by the team at work to-day. If 25-year forecasts were only to be begun from 1930, the probability was that none of the team would survive to digest them, and much interest and valuable experience would be wasted. *Third:* Rapid changes are taking place to-day, under modern developments, in Astronomy and other sciences, and the close *liaison* of these progressive tests at the present critical time helps materially to ensure that Drayson's claims are neither overlooked nor absorbed. The *Fourth* reason—really fundamental and primary—calls for some detailed explanation. Drayson's method of prediction is a simple one involving only solution of spherical triangles, as C P S and C P_2 S (Fig. 2). Let P and P_2 indicate the positions of the Pole at commencing and terminal epochs of the forecast; obtaining from the *N.A.* of the year of start

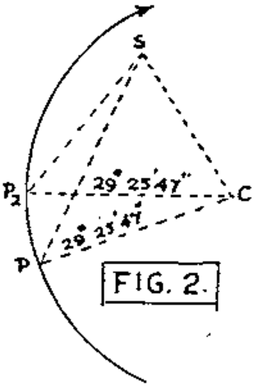


FIG. 2.

the position of star S, he found, by easy calculation, its constant distance from centre C. The star's polar distance, S P, also was obtained from the *N.A.*, and the base C P (radius of the precessional circle) he had already found to be 29° 25′ 47″ and constant for all stars. Thus with three sides he solved the triangle and obtained the angle at C. For the triangle C P_2S he then had two sides, C S and C P_2, and, multiplying the annual variation of angle C by the years of forecast, he found the residual angle at C, or S C P_2, and solved the triangle to obtain P_2 S. Now, on the surface it would appear as if the rate of variation of angle C should be constant for all stars, at the rate of second rotation, or 40.9″, as applicable to most; but this is not the case, the annual variation for some stars being affected by their position relative to the co-ordinates, in a very remarkable way, not easy of appreciation by any one who has not made intimate study of Drayson's research. Even to those who have, the method by which he arrived at the value for each several star is a well-kept secret, lost, with his private papers, at his death in 1901. With the hints that abound in his books it is hoped ultimately to rediscover the key, but meanwhile, the rates employed by Drayson in *Untrodden Ground*, and by ourselves in the extension tests, being applicable to epoch 1887.0, we are for the present tied to that epoch for a start.

The 1933 tests were opened at Reigate on August 30th, 1933, present: Prof. Stratton, Lieut.-Colonel Murray and Lieut.-Colonel Skinner. The Cambridge packet contained two sets of forecasts. In accordance with the set terms these should have started from the mean places of *N.A.* 1896.0, one of them, known as "Cambridge A" using "the best values for the p.m's now available," the other, known as "Cambridge B_2," "using the p.m's of *N.A.* 1896," for adjustment back to 1887; but, on reinspection at a later date, it was seen that in neither case had the conditions been fulfilled, set A starting from 1925, while B_2, though correctly dated from 1896, had not been adjusted back to 1887, the precise conditions having apparently been overlooked. They had, therefore, to be referred back for recasting, comparison of the revised figures with *N.A.*, *Observation* and the Drayson forecasts being ultimately made on January 30th, 1934, with results as scheduled below:—

Forecast—1887 to 1933=46 years.—(Polar distances)

STAR.	*Naut. Alman.*	*Obsn.*	*Camb.A*	*Camb.B_2*	*Drayson*
γ Pegasi.	**75° 12′ 19.55″**	**20.02″**	**19.78″**	**19.98″**	**19.51″**
α Urs. Minor.	1° 4′ 22.68″	22.72″	22.50″	23.20″	20.00″
α Aurigae.	**44° 4′ 4.94″**	**5.49″**	**5.73″**	**5.94″**	**3.44″**
β Leonis.	**75° 2′ 12.11″**	**12.32″**	**12.16″**	**11.55″**	**11.32″**
α Virginis.	100° 47′ 43.63″	43.79″	43.64″	43.31″	44.47″
α Libræ.	105° 45′ 51.67″	51.92″	51.29″	51.68″	50.67″
α Scorpii.	116° 16′ 5.23″	5.53″	5.44″	5.84″	6.51″
β Draconis.	37° 38′ 58.79″	59.01″	58.92″	59.41″	60.97″
γ Draconis.	**38° 30′ 13.98″**	**14.23″**	**14.50″**	**14.93″**	**17.06″**
α Lyræ.	51° 16′ 46.93″	47.35″	47.11″	46.42″	49.12″
α Cephei.	27° 42′ 55.48″	55.62″	56.19″	56.89″	58.54″
α Aquarii.	90° 39′ 45.52″	45.83″	45.27″	44.91″	45.72″

Analysis of these results will be made later, along with those of 1936 and 1940 Here it will only be noted that, as in 1930, while some drift away from *N.A.* and/or *Observation* is noticeable in some of the *beam* and *intermediate* stars, the reactions of the *fore-and-aft* stars continue excellent.

The 1936 tests were opened in London on November 12th, 1936, present: Prof. Stratton, Lieut.-Colonel Murray, Brigadier McLeod, and Lieut.-Colonel Skinner. Delay again occurred in obtaining correction of the Cambridge A (1925 datum) and B_2 (1896 datum) back to 1887, and it was not till February 9th, 1937, that the results, as under, were finally scheduled:—

Forecast—1887 to 1936=49 years.—(Polar distances)

STAR.	*Naut. Alman.*	*Obsn.*	*Camb.A*	*Camb.B_2*	*Drayson*
γ Pegasi.	**75° 10′ 19.48″**	**20.05″**	**19.70″**	**19.94″**	**19.43″**
α Urs. Minor.	1° 2′ 28.12″	28.31″	27.95″	28.69″	25.00″
α Aurigae.	**44° 3′ 53.66″**	**54.51″**	**54.45″**	**54.65″**	**51.87″**
β Leonis.	**75° 4′ 12.47″**	**12.69″**	**12.52″**	**11.87″**	**11.65″**
α Virginis.	100° 49′ 40.07″	39.90″	40.08″	39.71″	41.01″
α Libræ.	105° 46′ 36.69″	36.59″	36.31″	36.72″	35.70″
α Scorpii.	116° 17′ 29.41″	29.81″	29.62″	30.06″	30.82″
β Draconis.	37° 39′ 6.87″	6.99″	7.00″	7.52″	9.21″
γ Draconis.	**38° 30′ 15.32″**	**15.56″**	**15.85″**	**16.30″**	**18.58″**
α Lyræ.	51° 16′ 37.00″	37.46″	37.18″	36.42″	39.35″
α Cephei.	27° 41′ 9.77″	10.00″	10.48″	11.22″	13.09″
α Aquarii.	90° 37′ 53.13″	52.35″	52.87″	52.50″	53.38″

Here again we need merely note the drift of some *beam* and *intermediate* stars along with the precision of forecast in the case of the *fore-and-aft* stars. Detailed analysis later.

In the exigencies of war it was found impossible to arrange a conference for the 1940 results, but, not to delay matters indefinitely, Prof. Stratton kindly sent the sealed envelope containing the 1940 tests. This was opened in London on April 16th, 1941, by Brigadier McLeod and the author, the Cambridge series being then adjusted to datum 1887 and the results scheduled as below :—

Forecast—1887 to 1940 = 53 years.—(Polar distances)

STAR.	*Naut. Alman.*	*Obsn.*	*Camb.A*	*Camb.B$_2$*	*Drayson*
γ Pegasi.	**75° 8′ 59.39″**	—	**59.62″**	**59.84″**	**59.31″**
α Urs. Minor.	1° 1′ 15.68″	15.74″	15.50″	16.19″	12.24″
α Aurigae.	**44° 3′ 38.71″**	**38.83″**	**39.51″**	**39.74″**	**36.48″**
β Leonis.	**75° 5′ 32.96″**	—	**33.02″**	**32.33″**	**32.08″**
α Virginis	100° 50′ 55.30″	—	55.30″	54.92″	56.19″
α Libræ.	105° 47′ 36.67″	—	36.28″	36.76″	35.71″
α Scorpii.	116° 18′ 01.58″	—	01.79″	02.26″	03.21″
β Draconis.	37° 39′ 17.62″	17.60″	17.74″	18.30″	20.29″
γ Draconis.	**38° 30′ 17.09″**	**17.16″**	**17.61″**	**18.10″**	**20.69″**
α Lyræ.	51° 16′ 23.72″	23.79″	23.91″	23.08″	26.24″
α Cephei.	27° 40′ 08.80″	8.77″	09.51″	10.34″	12.39″
α Aquarii.	90° 36′ 43.24″	—	42.99″	42.56″	43.59″

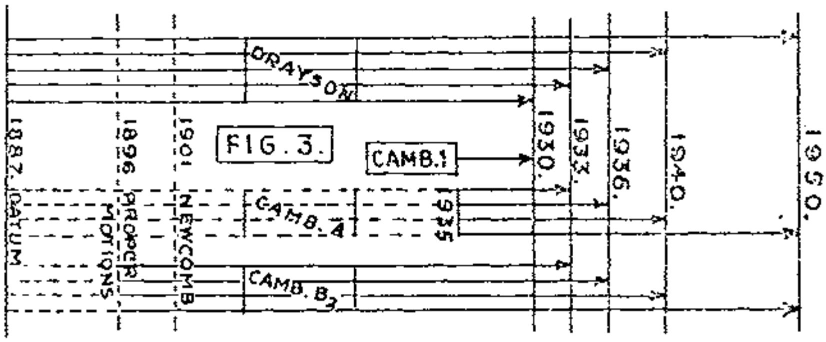
Note again the precision of forecast of "fore-and-aft" stars with the continued drift of some "beam" and "intermediate" stars. This will be more readily seen in the subjoined synoptic table showing the discrepancies between the "Drayson" forecasts and the positions indicated by the *Nautical Almanac* at each of the four epochs now under discussion. Note also with regard to the "intermediate" stars (α Urs. Min. and α Cephei excepted) the increasing defect as they remove from "fore-and-aft" towards "beam" positions; γ Draconis, which is virtually "on the beam" being always the leader. Polaris and α Cephei are exceptions to the general run of "intermediate" stars. Their situation relative to the co-ordinates is peculiar, and, as Drayson showed, their reactions will always be different. This calls for an article by itself and perhaps later the Editor may permit of a detailed explanation.

Synoptic Table of the Tests from 1887 to 1930-33-36-40.

Discrepancies between the Drayson forecasts and *N.A.* Mean Places.

STAR.	1930	1933	1936	1940	*Camb.A* 1940	*Camb.B$_2$* 1940
γ Pegasi.	**—0.01″**	**—0.04″**	**—0.06″**	**—0.08″**	**+0.23″**	**+0.45″**
α Urs. Minor.	—2.52″	—2.68″	—3.12″	—3.44″	—0.18″	+0.51″
α Aurigae.	**—1.23″**	**—1.50″**	**—1.80″**	**—2.23″**	**+0.80″**	**+1.03″**
β Leonis.	**—0.73″**	**—0.79″**	**—0.85″**	**—0.88″**	**+0.06″**	**—0.63″**
α Virginis.	+0.73″	+0.84″	+0.94″	+0.89″	±0.00″	—0.38″
α Libræ	—1.01″	—1.00″	—1.00″	—0.96″	—0.39″	+0.09″
α Scorpii.	+1.15″	+1.28″	+1.39″	+1.63″	+0.21″	+0.68″
β Draconis.	+2.00″	+2.18″	+2.40″	+2.67″	+0.12″	+0.68″
γ Draconis.	**+2.81″**	**+3.08″**	**+3.24″**	**+3.60″**	**+0.52″**	**+1.01″**
α Lyræ.	+1.99″	+2.19″	+2.39″	+2.52″	+0.19″	—0.64″
α Cephei.	+2.94″	+3.06″	+3.38″	+3.59″	+0.71″	+1.54″
α Aquarii.	+0.16″	+0.20″	+0.26″	+0.35″	—0.25″	—0.68″

In the above table are included for comparison the Cambridge A and Cam-B_2 discrepancies for 1940 only. Camb. A offers a practically perfect result, but, since, though adjusted back to 1887, it actually starts from 1925, *i.e.*, 38 years later, a big advantage in precision to begin with, while the Drayson tests are handicapped in having to take in their stride the changes of method of 1896 (proper motions) and 1901 (Newcomb's formulæ) it is of little use for comparison. Cambridge B_2, on the other hand, offers somewhat better value for comparison, though even it has the benefit of 9 years later start, " Drayson " being also handicapped by the two changes of method. These various handicaps are illustrated in the following sketch :— Fig. 3.



In addition to the foregoing formal tests, Colonel Murray has worked out " Drayson " forecasts for the following intermediate years, *viz.* :—1895, 6, 7, 8, 9, 1900, 1, 5, 10, 15, 18, 20, 25, 35, 37, 38 and 39, seventeen in all. Comparison of these with the *N.A.* reveals the same consistency of reaction throughout as the years of formal test, *viz.* :—perfect coincidence fore-and-aft ; progressive displacement on the beam. The results will now be analysed.

1. *Fore-and-aft Stars.*—The four stars, γ Pegasi (near 0/24 hours), α Aquarii (near 22 hours), β Leonis (near 12 hours) and α Virginis (near 13 hours) show no appreciable discrepancy for 1940, in strict keeping with like results for the three earlier years of test, and for the 17 intermediate years as well ; affording confirmation of correctness of 29° 25′ 47″ as the measure of C P, the radius of second rotation and base of all the Drayson triangles.

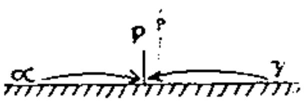
2. *Beam Stars.*—The principle beam stars, α Aurigæ (near 5 hours) and γ Draconis (near 18 hours), show, for 1940, discrepancies of -2.23 and $+3.60$, respectively, in strict keeping with the rising scale disclosed in the earlier years.

3. *Intermediate Stars.*—With two exceptions, α Cephei and α Urs. Min., already referred to, and α Libræ (see 6 below), all the " intermediate " stars, show consistently graded discrepancies, increasing from minimum, near the 0/24 hours–12 hours (equinoctial) colure, to maximum near the 6 hours–18 hours (solstitial) colure ; all being confirmed by the 17 unofficial tests.

4. *Divergences.*—From 2 and 3 it appears that between the *N.A.* and " Drayson " determinations there is a slow, cumulative divergence along the 6 hours–18 hours line amounting in 1940 to 3.60″ and working out at the rate of 1.00″ in every 14.7 years. Allowing for slight differences in calculation from year to year, the rate will be found, on examination, to be regular throughout the whole 53 years period, and, for practical purposes, may be taken as one second of arc in every 15 years. It is not possible to invoke the *Nautical Almanac* for more than two or three years in advance, but, on the " orthodox " assumption that Newcomb's formulæ will hold good for a hundred years, or more, and that correspondence with observation will be reasonably good, we can, in effect, secure a useful comparison now, by merely forecasting for γ Draconis on the two formulæ, for a convenient future date, say A.D. 2000, and comparing

results, and this Colonel Murray has already done, the results for A.D. 2000 being:—Newcomb: 38° 36′ 41.93″, and Drayson: 38° 30′ 49.35″. The difference, or 7.42″ represents thecumulative divergence in the 113 years since 1887, and works out at practically one second in every 15 years for the whole period. The calculations are subject to correction, but no great difference is likely to be found, and the rate of 1″ in every 15 years will serve future use as a "yard-stick."

5. *Direction of Divergence.*—The significance of the plus and minus signs of these divergences should also be noted, all four stars on the 6 hours side being negative, while all on the 18 hours side (with one exception α Libræ) are positive. Regarding these as shots at a mark, P, from opposite directions α and γ, it will be seen that while all on the 6 hours side fall short, all, save one, on the 18 hours



side go over; a result that, given good marksmanship, might most easily be attained by shifting the target to P′ while the shots are in the air.

6. *The Case of α Libræ.*—Results of all tests of this star from 1887 to 1940, 22 in all, lie between a minimum of 00.17″ and a maximum of 01.55″, all being minus. Unlike the other seven intermediate stars on the 18 hours side, the results for this star show no persistent increase, but a gentle rhythm around the average discrepancy of about 1.00″. It is understood to be a binary star. Explanation of the negative sign is yet to be found, though it should not be taken, it is thought, to discredit the uniform testimony of the seven stars with positive sign.

7. *Observed Results.*—The mean observed places of the twelve stars for January 1st, 1930, were those "secured at Greenwich during the year 1929." For 1933 they were obtained from the Astronomer Royal in November of that year. For 1936 they were taken "from observation at Greenwich (transit circle) between 1931 and 1935," the Astronomer Royal explaining that "It was not possible for some of the stars to give places from 1935 observations only." The six results asked for for 1940 were, it is understood, taken from the F.K.3 catalogue, a general compilation. These details are given to illustrate the difficulty of arriving at a satisfactory criterion for correctness of test. It may also be mentioned that of all 42 "results of observation" here recorded, while in 5 instances the *N.A.* figures are higher, in the remaining 37 instances the *N.A.* figures are lower.

8. *Appraisal of Results.*—Prof. Stratton is of opinion that unless the Drayson theory be modified by acceptance of proper motions, the results so far are conclusively against the Drayson claim; but that if proper motions be accepted, the tests are inconclusive, and only long forecasts showing wide divergence can determine the truth or falsity of either theory. We, on the contrary, take a totally different view. In our opinion the tests are confirming the Drayson claim all the time. The results bear searching examination now and the more closely they are studied, the more we submit, do they point the truth and significance of Drayson's discovery. This will be resumed later, but before the matter can be intelligibly set out attention needs be given to the following important considerations:—

9. *The "Orthodox" Movement of the Ecliptic Pole.*—The accompanying diagram (Fig. 4) illustrates the movement of the ecliptic pole as held by "orthodox" astronomy. The diagram is similar to the one used by Newcomb in *Spherical Astronomy*, p. 226, but inverted, as if viewed from without the sphere, and with lettering altered to agree with general use in this article. The "orthodox" belief is that the pole of the heavens, P, moves in a small circle towards the equinox Ex, round the pole of the ecliptic E, as centre, while E, itself has a small movement towards E′. On page 229, for clearer definition, Newcomb states that "The curve E E′, along which the pole of the ecliptic is moving in

our time is not a great circle but a curve slightly convex towards the colure E P." On p. 228 he says: "Hence at the present time the pole of the ecliptic is approaching that of the equator."

Drayson showed very clearly in *Untrodden Ground*, pp. 232, 3, 9 to what theoretical assumption the alleged movement of the ecliptic pole was due, the argument being as follows:—Let O P Q R (Fig. 5) indicate—according to Drayson's determination—the circular arc being traced by the pole of the heavens round its true centre C, six degrees from E, the pole of the ecliptic. Then the radius C O, C P, etc.$=29° 25' 47''$ and C E$=6°$. The obliquity at any particular epoch will therefore be represented by E O, E P, etc., and will be a minimum when the pole reaches R, in line with E and C. At some remote date when the pole was at O, a star x, on the meridian joining O and C, would neither increase nor decrease its polar distance noticeably; *i.e.*, for a brief period O would not vary its distance from x, and, in the belief that the pole of the heavens was describing its circle round the ecliptic pole as centre, it would follow that the ecliptic pole must be conceived to lie somewhere on the arc O x C, its whereabouts being determined by measuring off along O C an arc O A equal to O E, the obliquity at that particular date. Continuing its uniform movement round C,

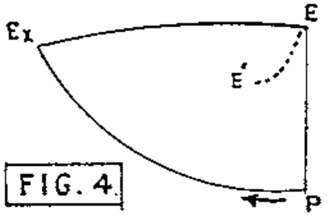


FIG. 4.

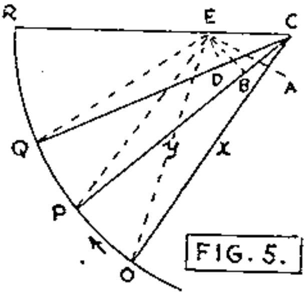


FIG. 5.

the pole of the heavens would reach P, at which epoch a star y on the arc P C would not increase or decrease its polar distance for a short period. It would therefore be assumed that the pole of the ecliptic was on the arc P y C, and at a distance P B, from P, equal to P E, the obliquity for that date. B would therefore be the assigned position of the ecliptic pole for that date. And so on. The parallelism of the curve thus traced by the moving E, with the one indicated by Newcomb as convex towards the colure E P, will be apparent; and that they are one and the same will be further evident from what Drayson has shown, the movement having two components in each case, a lateral one relative to the radii C O, C P, C Q, etc., and a direct one towards the pole of the heavens, the components for epoch 1887 being, lateral$=4.2''$, direct$=0.46''$, the direct component being precisely the amount of the annual decrease in obliquity for the year in question; the resultant movement assigned for that epoch would be about $4.3''$ per annum.

Hence it has followed that, through non-recognition of the circular path of the pole of the heavens round centre C, a continual readjustment of the ecliptic pole has been necessary, to reinstate it from time to time as point of reference within the frame thus distorted.

10. *The Real Movement of the Ecliptic Pole.*—That the ecliptic pole has a real movement is not in dispute. What is questioned is its direction and the amount assigned thereto. If the ecliptic plane moves, so must its pole. Dynamical theory and mathematical determination have shown that under conspiring attractions of other elements of the solar system, the plane of the earth's orbit is swayed so as to give it a very gentle rocking motion relative to the "invariable" plane, as the theoretically average position is called. No precise limit has yet been or

probably ever can be, set to either the periodicity or the extent of the movement. Herschel, in *Outlines*, Art. 640, hazarded the amount of deviation at less than 1°21′ on either side of the mean position "in an immense period of ages." *Encyclopedia Britannica*, vols. 7, 8, p. 895, states :—"When the problem is considered in a rigorous form, it is found that no absolute limits can be put. It can, however, be shown that the obliquity cannot vary more than 2 or 3 degrees within a million years of our epoch." From these extracts it is clear that though a movement of the ecliptic pole is envisaged of immensely long periodicity, anything like a detailed trace must be open to challenge.

Then as regards direction : The pole of the ecliptic is supposed to be approaching the pole of the equator at the present time—Newcomb (see 9 above)—but, by analysis of longitudes of stars between A.D. 140 and A.D. 1660, Drayson showed (*M.F.S.*, Chap. VI) that support for such assumption was not forthcoming throughout that long period of 1,520 years, and his contention we have confirmed to date by like analysis of later figures between 1660 and 1943. Our submission, therefore, is that the orthodox theory which attributes the annual decrease in obliquity of 0.46″ to a movement of the ecliptic pole is nothing other than the legacy of error deriving from the original supposition that E, the ecliptic pole, for all present practical purposes a fixed point, was centre of the earth's second rotation and itself in considerable motion towards P.

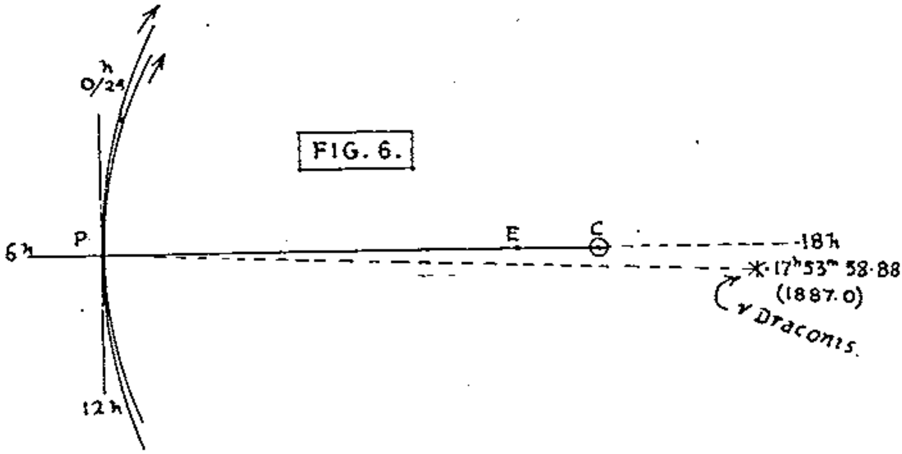
11. *Locus of C, the Centre of Second Rotation.*—Likewise we submit that C, the pole of second rotation, is to all intents and purposes a fixed point ; nevertheless the aforementioned theoretical movement of the ecliptic pole, a fundamental point of reference, causing it to "cover" C, the true centre, at any and every epoch, inevitably so affects the compilation of the *Nautical Almanac* as to necessitate assignment of an unreal movement to centre C, itself, to rectify the position when employing the *N.A.* in solving triangles for "Drayson" forecasts. This will be made more clear if we consider that at epoch A.D. 2295 (see Fig. 1), by Drayson's determination, P, the pole of the heavens, E, the pole of the ecliptic, and C, the pole of second rotation will all be in line, or, in other words, E and C will transit simultaneously, giving us the positions of E and C for that date, P E being minimum obliquity, or 23° 25′ 47″ and C E being 6°, the r.a. of C being 18 hours exactly. By the same determination the last previous simultaneous transit of E and C would have occurred at 13544 B.C. At no other dates would they transit simultaneously, the intervals and precedence of transits depending on the position of the pole P, in its precessional circle. At A.D. 1887, for example, C would have transited 4′52.10″ before E, its r.a. at that date being $17^h55^m7.90^s$. But, by the effect of the orthodox theory E being located always on the P C meridian, and the *Nautical Almanac* being so compiled, a right ascension of 18 hours is automatically decreed for C, for all epochs, and by it we have to abide when calculating by Drayson's formula from *N.A.* star positions. We are now in a position to appreciate the results referred to in Section 8.

12. *Displacements "On the beam."*—In the diagram (Fig. 6) we can test a possible movement of the centre C by the reaction of the *beam* star γ Draconis. This star, as is to be expected, shows the maximum displacement, amounting in 1940 to 3.60″, its right ascension (1887) being $17^h53^m58.88^s$, or only about 6 minutes short of 18 hours, and furnishes us with the "yard stick" of one second of arc in every fifteen years. The diagram is drawn roughly to scale, C P being 29½°, E P 23½°, C E 6°, and P γ 38½°. Around C is drawn a little circle of ½° radius. Assuming for argument a possible displacement of centre C, our yard stick shows that it would take 27,000 years to move C from centre to circumference of the little circle of half-degree radius—practically an entire cycle of precession—and C would even then be 5½ degrees away from E, the ecliptic pole. But in considering the decrease in obliquity of 12°, or from 35½° maximum to 23½° minimum, we are concerned with only the half cycle of precession, or about 16,000 years, during which time a displacement of C, at 1″ in every 15 years, would amount to less than 18′. The rate might therefore be doubled without seriously affecting the claim to such decrease. What then becomes of the "ortho-

dox " claim that E is true centre of precession ? It has been said—and will no doubt be repeated—that we may not extrapolate from small arcs of observation. If so, what are we to understand of the " orthodox " precessional cycle of 25,800 years itself ? Is it not an extrapolation pure and simple ? And what of the comets ? Are not their orbits extrapolated from the little we learn of them when they come under observation ? Yet they keep schedule time. The drift, we submit, is entirely due to other cause.

13. *The Frame of Reference.*—For sake of argument we have considered the possibility of C having some movement to account for the displacement shown by the *beam* stars. The result shows that it makes no practical difference to Drayson's claim, and we make no concession on that point. Instead we submit that the displacement is directly due to the " orthodox " interpretation of the annual decrease in obliquity as arising from a movement of the ecliptic pole E, towards the pole of the heavens P, by reason of which the fundamental point E, origin of the frame of reference, is being continually shifted along the solstitial

FIG. 6.



colure, rectification being made at the circumference for maladjustment at the centre. This we submit, is substantiated by the accuracy of forecast with the *fore-and-aft* stars, these being unaffected materially by the lateral drift. And, further, consider the following :—

Prior to 1887 (the year from which Drayson's back-casts were made), and up to 1900, it is understood that the *Nautical Almanac* was compiled by short range predictions based on continual observation, mainly at Greenwich, results being closely watched and rectified as necessary in subsequent issues. Consequently the movement of E towards P, though held in theory, did not affect the *N.A.* compilation. But the adoption in 1901 of Newcomb's formulæ, already referred to, having rendered possible compilation for considerable periods in advance by calculation only, from that time forward, after sufficient probation, it would seem that observational check had been somewhat relaxed. The use of Newcomb's formulæ, however, being based on an assumed movement of E towards P, necessarily, we submit, affected the *N.A.* figures, by giving the reference frame with E as origin a continual shift and, to that extent throwing out of their stride all Drayson forecasts on the beam stars. That here we have to do with reality and not mere imagination is clear from the fact that the shifting frame manifests *even in the forecasts by Newcomb's own formulæ*, witness the 1940 results in Cambridge B_2 series in the synoptic table, where α Aurigæ and γ Draconis give worst results* of the series both over the 1" mark. Even the

*α Cephei alone excepted—as to which star, or rather to the difficulties attaching to its position in the sphere, Drayson has some illuminating disclosures in *U.G.* Chap. XII, for those who are interested.

Cambridge A series, starting from 1925, is unable to mask entirely the evidence of drift remaining after proper motions have yielded their quotas in adjustment.

14. *The Obliquity of the Ecliptic.*—So far mention has not been made of the O.E. tests by Drayson's formula. These were included in the originally agreed procedure and a forward test from 1887 to 1930 was added to the Drayson forecasts for that epoch. The result, 23°26′56.81″ against *N.A.* 23°26′54.21″, showed a discrepancy of +2.60″. Further forecasts were made for 1933, 1936 and 1940, the discrepancies being +2.91″, +3.22″ and +3.59″, showing the same precise drift towards 18 hours as was disclosed by the beam star tests for the same periods, notably γ Draconis, and indicating that both are due to the one cause.

15. *Variation of the Obliquity.*—With an open pair of scissors one may vary the opening by moving one blade or the other independently, or both simultaneously. In like manner the O.E.—obliquity of the ecliptic, or angle of inclination of ecliptic to equator—may be varied by independent movement of either plane or by both. But since Nutation, the only variation of tilt of the equatorial plane that meets the eye, so to speak, is both small and self-cancelling, it came to be believed that the only capability of changing the O.E. lay with the rocking of the ecliptic plane, and, dynamical investigation having limited that to 1½° either way, there followed the erroneous inference that no variation of obliquity could occur outside of 3°. But " Facts are chiels that winna ding," and our submission is that when due weight is given to Drayson's evidence for an obliquity of more than 35°, about 13,548 B.C., dynamical interpretation will be sought and doubtless found. Is there any such in sight now ? We believe there are several, any one, or all of which will repay study ; but space in this article limits us to statement of the known facts, and for the nonce it must suffice to have lifted an embargo that for too long has blocked approach from the meteorological side. This will now be considered.

16. *The Meteorological Effect.*—Regarding three only, of many possible variations of the obliquity—those of 12° and 3° and the minute oscillation of 18.5″ due to nutation—each increase of the earth's axial tilt necessarily extends the Arctic and Antarctic circles by equivalent amount, transferring from temperate to frigid zones additional areas of considerable magnitude, as shown in the following table based on minimum O.E. 23° 25′47″, at A.D. 2295.

Cause of Variation.	*Angular Increase.*	*Resultant O:E.*	*Area Trans. to Frig. Zone.*	*Total Area Transferred.*
Nutation	±18.5″ av.	22°26′5.5″	Abt. 4,340 sq. miles	Abt. 8,680 sq. miles
Tilting of Eclip.plane	Max. 3°	26°25′47″	Abt.2,000,000 sq. miles	Abt.4,000,000 sq. miles
2nd Rotation C as centre	About 12°	35°25′47″	Abt.10,000,000 sq. miles	Abt.20,000,000 sq. miles

From the foregoing it may be inferred that even the minute changes due to nutation may not be entirely without significance.

17. *Some Meteorological Factors.*—Opinion has been given by high authority that astronomical changes are insufficient to radically alter world climate, as they do not alter the amount of solar radiation received in the course of a year, but only change the difference between the summer and winter values. As to this, granted that with a constant obliquity, other things being equal, the summer heat should counterbalance the winter cold, with obliquity *increasing* it is submitted that the resultant creeping of ice fringes would reinforce the winter gains in two important ways :—(*a*) by the added reflecting power of expanding snow surfaces, tending to reduce insolation, and (*b*) by the holding power of

accumulating masses of ice and snow, tending to consolidate the gains against melting. A decreasing obliquity on the other hand, would start the reverse process by withdrawing support from the ice fringes, leaving them a prey to melting.

Applying these principles to the "great year" of Fig. 1, we get the astronomical setting according to Drayson, for the last glaciation, as under, the pole P, travelling at uniform rate from Z, through A, W, and S, back to Z, in about 31,687 years.

Point.	*Epoch.*	*O.E.*	*Rate of Increase or Decrease.*	*Effect.*
Z.	Midsummer 29392 B.C.	23½° Minimum	Pause	As the pole travels from Z to W the polar circles expand continually till W is reached, but with varying *rate* of expansion, accelerating up to point A, then decreasing down to point W.
A.	Autumn 21470 B.C.	29½° mean	4.27″p.a. Maximum	
W.	Midwinter 13548 B.C.	35½° Max.	Pause	
S.	Spring 5626 B.C.	29½° mean	4.27″p.a. Maximum	From W. to Z retreat sets in, the polar circles contracting continually till Z is reached, but at accelerating *rate* down to S, and then at diminishing *rate* up to Z.
Z.	Midsummer A.D. 2295	23½° Min.	Pause	

The above indicates the precise rates of expansion and contraction of the Frigid Zones, but not necessarily the rate of growth and decrease of the ice fields, as these latter will be affected by the (*a*) and (*b*) ("reflecting" and "holding") factors already referred to, others apart, and it seems probable that the accelerating rate from Z to A will, on that account, persist to W, and even beyond that turning point of maximum obliquity, while in the ensuing retreat the same factors will still be at work in retardation of melting till a crisis is reached and débâcle results, somewhere near S, the spring point of the "great year."

Thus visualized and without going too far back, the Drayson cycles fit remarkably well with the *Riss* and *Würm*, de Geer's two most recent phases of the Quaternary glaciations. In the second of these it may be noted that the ice shrinkage at both poles which we are now witnessing is but the expiring effort of retreat as the epoch of minimum obliquity approaches.

It may also be noted appropriately at this point that Croll's long term theory of glaciation at alternate poles, which for many years held undisputed possession of the field as THE astronomical theory, is now virtually abandoned as such in "orthodox" astronomy* though still probably useful in lesser degree as a contributory factor. At the same time, though claiming place for Drayson's discovery, as offering a more complete and satisfying astronomical clue than any yet put forward, it is recognized that it must rub shoulders with the fifty or more different theories of an ice age† that are said to exist, many, if not most of which probably play some part in the general result.

Uniformitarianism has decreed that the present is the key to the past, but in this connection we welcome Prof. Boswell's opinion recently expressed,‡ "that geological agents such as wind, sea or ice, may have at times operated with greater intensity than at present," and we invite attention to the magnitude of the forces released at the 'spring' crisis of the great year when, under an

*Astronomer Royal in *Discussion on Ice Ages*, *Q.J.* R.Met.S., April, 1936, pp. 285-7.

†C. E. P. Brooks in *World Climate during the Quaternary*, *Q.J.* R.Met.S., Oct., 1934, p. 472.

‡Boswell, *Climates of the Past*, *Q.J.* R.Met.S. July, 1940, p. 250.

obliquity annually decreasing at *nine times* its present rate, the ice accumulation of fifteen thousand years begins its discharge over land and sea, supplying at least a partial explanation of a universal flood of which so much reliable evidence exists.*

18. A word on the nature and sufficiency of the tests. Our colleague insists that forecasts of polar distances of the stars are sufficient of themselves to determine the truth or falsity of either theory of polar movement and that tests of right ascensions are entirely unnecessary. This we emphatically dispute, and for the simple reason that right ascensions enter into the make-up of Newcomb's formulæ for declinations and Drayson's triangles alike. Consequently errors in right ascensions are bound to creep in and affect the declination tests whether recognized or not. No tests of the two formulæ, therefore, from which examination of right ascensions is excluded, can of themselves be complete or satisfactory however valuable as far as they go.

Further we repeat that comparisons of the results by " Drayson " and " Newcomb," as *against the Nautical Almanac*, are unreal. This investigation has elicited the fact that the mean positions recorded in the *N.A.* for the twelve stars agree with the Cambridge " A " forecasts (unadjusted) from 1925 to 1933, 36 and 40 to within 1/100th of a second of arc, exactness too precise for attainment by any observation. Comparison with *N.A.* therefore merely remands the case of " Drayson v. Newcomb " to Newcomb for trial. As the *N.A.* is now compiled it is clear that " observed results " offer the only criterion of value, and these, as far as they have been obtained from the Royal Observatory, show a much more ragged edge not always favourable to Newcomb.

May not the modern practice of securing " observed results " for world-wide use by combining the work of a number of observatories, in different latitudes, tend to mask the errors that might be disclosed by more continuous and constant observation from one observatory selected as the most favourable, in much the same way as determination of sidereal time by reference to a number of " clock stars " near the equator, with the transit of the vernal equinox, masks the fact that stars situate within the polar precessional circle transit once oftener in the complete cycle than do those outside, as Drayson so long ago pointed out.

It is the age-old controversy between complexity and simplicity, or between " epicycles " and " axial rotation," and we submit that the position is one that calls for no part-treatment by unofficial tests with indefinite postponement of the serious practical issues involved, but for whole-hearted investigation of each and every one of Drayson's claims, cost what it may, among them the following :—

(*a*) The unrecognized displacement of the zeniths of the observatories (*U.G.*, pp. 164, 166, etc.).

(*b*) The so-called Apex of Solar Motion (*M.F.S.*, pp. 21-23 and 127, etc. and *U.G.*, p. 123).

(*c*) Cause of the supposed Acceleration of the Moon's Mean Motion (*M.F.S.* pp. 254-286) (or, alternatively, of the slowing down of the Earth's daily rotation) ; to rectify the timing of the eclipses and obviate changing the tide tables.

(*d*) Measurement of Time and Right Ascension (*U.G.* pp. 193-219, esp. pp. 197-8).

Our warm thanks, nevertheless, are due throughout to Prof. Stratton and Mr. H. E. Green for the help so generously given, failing which the results now recorded could not have been secured. The author desires also to record his appreciation of the sympathetic interest of meteorological friends, among them Dr. C. E. P. Brooks, Dr. F. J. W. Whipple, Sir Geo. Simpson, and Prof. D. Brunt, whose non-committal but ever-ready consideration of problems of the varying tilt have encouraged him to continue the investigation.

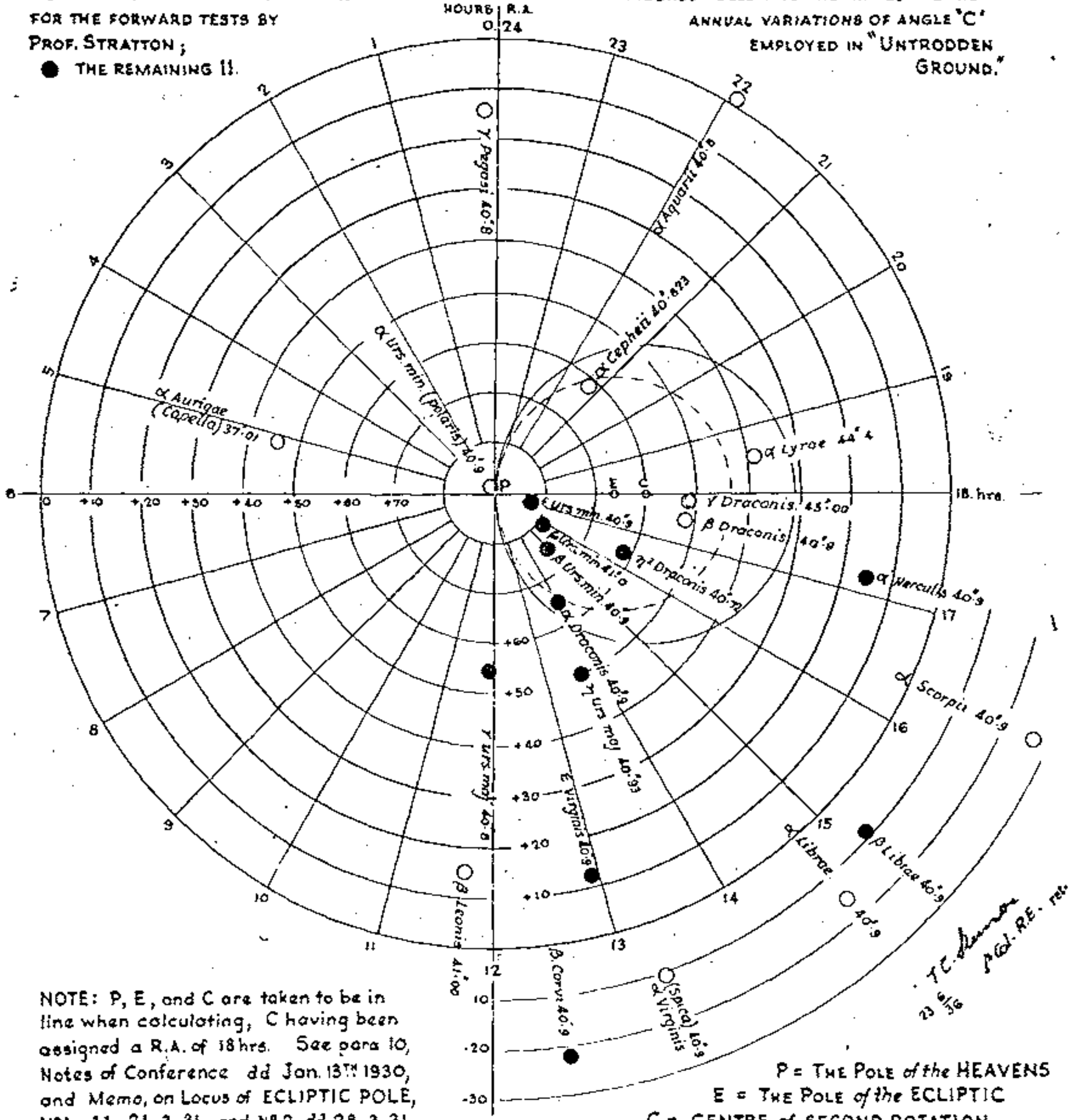
*Davies, " *Scientific Discoveries . . . and the Noachian Deluge*." *Trans. Vict. Inst*, 1930, pp. 62-85.

23 Stars employed by Drayson in "Untrodden Ground"

Epoch – 1st Jan. 1887.

○ Denotes the 12 stars selected for the forward tests by Prof. Stratton;
● The remaining 11.

Figures following the names are the annual variations of angle "C" employed in "Untrodden Ground."



NOTE: P, E, and C are taken to be in line when calculating, C having been assigned a R.A. of 18 hrs. See para 10, Notes of Conference dd Jan. 13th 1930, and Memo. on Locus of ECLIPTIC POLE, No. 1, dd 21. 3. 31, and No. 2, dd 28. 3. 31.

P = The Pole of the HEAVENS
E = The Pole of the ECLIPTIC
C = CENTRE of SECOND ROTATION.

THE MORNING DÂK.

By LIEUT.-COLONEL E. W. C. SANDES, D.S.O., M.C., R.E. (retd.).

THE scene is the Thomason College, Roorkee, some 13 years ago. In my office I find the usual forbidding pile of official correspondence and, on the top, a couple of notes from Indian members of the staff. One, the advance copy of a farewell address. " On your approaching retirement this present of an electric radiator has been selected by us in the hope that while it lies under your feet it may remind you of the warmth of our relations." The other, an expression of goodwill. "May the Providence keep you, Lady Sandes and Master Sandes O.K. is my heartfelt prayer. Amen. This prayer I will continue to make to the Almighty." Greatly cheered, I proceed to tackle the letters.

First, an official document from Lucknow in highly cynical vein. " Please report, under para. 7, regarding the domicile of your wife who requires a steamship passage. That para. states that, after marriage, a woman acquires the domicile of her husband provided that, if the husband and wife are separated by order of a Court, or if the husband is undergoing a sentence of transportation, the wife becomes capable of acquiring an independent domicile." To which I reply " Sir, I hereby certify that my wife and I are not separated by an order of a Court, nor do I happen to be undergoing at present a sentence of transportation. My wife is, therefore, of the same domicile as myself and, even in the painful circumstances referred to in para. 7, she would still be of non-Asiatic domicile."

An envelope from Vizianagram, re-directed to Roorkee, catches the eye. It is addressed to " The Principal, The New Mechanical Engineering College opened by Germans, Ludhiana, Punjab." So it seems that the Hun is already at work; but discreet enquiry produces no result and the mystery remains unsolved. Another envelope, coming from Razmak, is addressed to " The Curator (Skin), Thomason College, Roorkee." I pass it to the Curator of the College Library who finds this letter within. " Sir, Will you kindly let me know whether there are any arrangements in the College to cleanse Dear Skins. If not, please tell me of place where such arrangements are operated in India as I wish to send the skin for such purifications."

An application, intended apparently for the Collector at Saharanpur, ends " I would deem it a matter of ecstasy if you could leniently take one of my darling nephews in the Civil Police line as a constable," and another, correctly addressed, says " Being given to understand that some *duffers* are required in the workshops of your College, therefore I beg to offer myself as a candidate for one of them."

But what is this? Something more serious. The offer of a bribe. " My dear Sir, Please read this letter carefully for God's sake. I have great pleasure to introduce myself to your Honour for the first time, which I trust will impress the following ideas on your wise and clear mind and would prove efficatious. Your Honour sanctioned my admission to College on payment of Rs. 1,000 yearly for which I shall sincerely pray God for your long life and prosperity. My father when I appeared for Entrance Examination, was alive, but after one month he breathed his last because he was ill for the last three years, which illness washed all the money from my house. So your Honour can easily bring back to your clear head that I won't be able to pay Rs. 1,000 yearly. Even if I cry 1,000 times I cannot have Rs. 1,000 in compensation. I therefore highly request your Honour to anyhow remove this burden of Rs. 1,000 yearly. For this trouble I shall make amends by giving Rs. 100 or Rs. 200 and a good present and Bottle of Brandy which will make you merry for helping a poor who was drowning in a deep ocean of circumstances. Hoping to be favoured with an early reply by wire so there may be no delay for your compensation of Rs. 100 or Rs. 200 as you like. If you show such kindness and generosity I shall think that Heaven has smilled Beneficiently upon the whole world and your Honour. Reply at your earliest convenience. I shall pay for this trouble caused to you. Believe me, yours affectionately, etc."

Further down the pile is a pathetic appeal headed "*Sweet Mercy is Nobility's true badge.*" "Revered Sir," writes the petitioner. "Although an unknown and castaway youth like myself has no claim on your precious time I am still constrained to take advantage of the generosity of your heart and the wideness of your sympathy. In the name of God and Sweet Mercy I resign myself wholeheartedly to your much-heard-of clemency. In vain did I pass the Intermediate Examination in Science of the Calcutta University at the age of 19, for with all my this and other qualifications, if qualifications they be at all, I am in the deepest abyss of darkest despair and ignorance. A regular and well behaved student I had been all through my school and college career, and they all predicted, on warrant even, I would make a man of myself in future. I too, believe me Sir, have been feeling since my boyhood an impulse for a practical man. Circumstances would not permit me to pursue the aim of my life through a regular course, and my parents, who can barely maintain this large family, did not hesitate to discard me as a total failure. Thus became I a helpless and forlorn castaway, cast adrift in the vast ocean of mental perplexity and struggle for existence with but one hope—idolized quietly and secretly at the bottom—that I may yet see brighter hours. My last resource for your conviction are my University and character certificates. Hoping to be excused for this intruding botherance." I sympathize with the forlorn castaway, but unfortunately the rules admit of no relaxation.

I dip deeper and many dry, official letters come to light. Some can be dealt with forthwith; others require laborious enquiry and much expenditure of ink. In a moment of relaxation I take up the *Pioneer* and in it find a small notice entitled "Rajput Marriage—Wanted—Beautiful Educated Girl (not plumbodied), aged about 18, for marriage of a Raja's eldest highly educated son with over a *lac* yearly income. Raja's family highly flourishing (unencumbered). Needy families of position may apply to ——." With added zest I seize the next letter in the pile, one from Sargodha. "Dear Sir, I shall feel much obliged by your kindly placing the enclosed notice on the Notice Board of your College for the information of your College scholars. I trust you will regard it as a piece of purely philanthropic work. *Notice.* Wanted—Bachelors for my two nieces, aged 17 and 15 years, of respectable Bungahi family, beautiful, well accomplished, Middle passed and qualified in Arithmetic, Geography, History, Hindi, Cooking Needlework, Laundrywork, etc.; know English also. Parents living. Father, a pensman at Amritsar. Caste immaterial, but Punjabees of Samajist views preferred. Desiring youths about to enter life may correspond direct or through parents."

Finally, at the bottom of the pile is a tale of adventure. "Sir, I went out for Survey reconnaissance with Messrs. Dickshit and Agarwal on 22nd March. On our return journey we came across a wild buffalo. Mr. Dickshit got afraid of him and began to run. Naturally the animal grew wild and followed fast upon us. Myself and Mr. Agarwal then had also to run for our life. As I was closest to the animal he soon gained upon me, and in desperate attempt to escape, I fell down in a thorny bush and got badly bruised. The buffalo was instantly upon me and made an attack with his forehead. In my utter desperation I tried to caress him and petted his forehead; and as luck would have it the animal got pacified and was tamed. I was thus saved from the Clutches of Death."

And so I reach the end of the morning mail. At least it has been a varied assortment and not without entertainment.

Major General Sir Hugh B Bruce-Williams KCB DSO
Colonel Commandant

MEMOIRS.

MAJOR-GENERAL SIR HUGH B. BRUCE-WILLIAMS, K.C.B., D.S.O., p.s.c.† COLONEL COMMANDANT R.E. (ret.).

MAJOR-GENERAL SIR HUGH BRUCE-WILLIAMS, "Billy Williams" to his many army friends, from 1930 to 1935 a Colonel Commandant, died at his home near Crowborough, Sussex, on the 14th December. Pollock medallist, cricketer and horsemaster, he was a distinguished guide of night marches and Intelligence officer in the S. African War, chief of the General Staff of an Army and commander of a division in 1914-18; from 1935 to 1938 he was President of the Council of the Institution of Royal Engineers, and in the present war raised a battalion of the Home Guard in East Sussex.

Born on 24th July, 1865, he was the only son of General Sir Edward Williams, K.C.I.E., R.E. (Bengal) and the elder daughter of Thomas Bruce, of Arnot, Kinross-shire, whose surname he assumed in 1920 as a distinguishing addition. He was educated at Winchester and entering the R.M. Academy in 1883, was Senior Under-Officer and left it as head of a batch, receiving the Sword and most of the prizes. At the end of his course at the S.M.E. he was posted to the 23rd Field Company at Aldershot, a year later being transferred to the 1st Division of the Telegraph Battalion. Exchanging to stay at home, he served in the G.P.O. Telegraphs at Exeter and Basingstoke, the R.E. being in those days in charge of the telegraph system in the South of England. Promoted Captain in 1894, he was two years later appointed adjutant R.E. Troops Aldershot. He passed into the Staff College, in 1898, but on declaration of war in October, 1899, was posted to the 11th Field Company, and with it went to South Africa and took part in the advance on Kimberley and Pretoria, serving under Colonel Arthur Paget. He acquired a special reputation for organizing night attacks, fighting horse-sickness and horse-mastership. In 1901 he was transferred to the Staff as D.A.A.G. Intelligence, serving under Colonel Walter Kitchener and Colonel Herbert Plumer, who ever after were his staunch friends. Often he would be absent for days at a time, and returning, with accurate information, would recover from his fatigue by an 18-hour sleep. He received a brevet majority at the end of 1900, a D.S.O. next year, and was four times mentioned in despatches.

On return to England he took over a section in the Intelligence Branch, War Office, under Colonel (later F.M. Sir William) Robertson, which became noticeable even under that exacting Chief for the hard work which it put in. After the General Staff had been called into existence by Lord Haldane, Williams was appointed Major G.S. on the staff of the Southern Command; but after a year he was broughtback to the Corps as Brigade Major and Secretary, S.M.E. Shortly after, however, when it was ruled that R.A. and R.E. officers were eligible for half-pay lieutenant-colonelcies, he, with the late Lieutenant-General Sir Montagu Harper, was given the first of this nature of promotion, and appointed G.S.O.2 of the Eastern Command, London, under his old chief, General Sir Arthur Paget. Four years later, on the expiration of his tour of staff service, he was given a similar appointment in the Irish Command, Dublin, again under Paget, and awarded a brevet-colonelcy.

Sir Arthur Paget, in the preparations for war, was earmarked to command the III Army Corps and Williams would have gone to France on his staff; but Sir John French (later Lord Ypres), after a dispute with Paget over the Irish troubles, refused to take him as a corps commander, and thus Colonel Williams, his original war assignment having lapsed, came to be appointed to command No. 1 Base (Havre) in France; but in November, when the Indian Corps was arriving, he was promoted to command the Southern Line of Communications with headquarters at Marseilles, a few months later receiving a C.B. for his services. In July 1915 he was rescued from back area work by his old friend, General Sir Herbert Plumer, then commanding the Second Army, and appointed his chief General Staff officer in succession to Major-General (later Field-Marshal Lord) Milne. It fell to him, therefore, to supervise the preparations for the Messines attack of 1917, originally planned for mid-1916. But the Second Army did not participate in any great battle in the next 12 months, staging only minor operations at Hooge, Bellewaarde, the Bluff, St. Eloi, Wulverghem and Mount Sorrel.

The almost static duties of the chief General Staff officer of an Army, back in an office at Cassel, with a force and material too small to undertake any serious blow, irked Williams, and in June, 1916, he obtained command of the 137th Infantry Brigade of the 46th Division (Allenby's Third Army), which on the 1st July, 1916, took part in the Battle of the Somme in the expensive diversion attack at Gommecourt. His services were recognized by his promotion on the 9th November, 1916, to command, in succession to an invalided major-general, the 37th Division in Gough's Fifth Army. Thus, by the force of circumstances, he became junior as a major-general to Harper, who from G.H.Q. had gained command of a brigade in January, 1915, and a division in September, 1915, and proceeded to a corps in March, 1918. With the 37th Division, originally formed in April, 1915, from "oddments," with no territorial connection, Williams remained until the end of the war. He gradually worked it into a first-class division, celebrated not only for its discipline and fighting qualities, but also for its wonderful transport, with horses which it was a delight to look upon. Henceforward the 37th Division saw much fighting, always with credit. Immediately after his arrival, 13th-18th November, it was thrown into the Battle of the Ancre, the closing phase of the Battles of the Somme. In 1917 it took part, in Allenby's Third Army, in three phases of the Battles of Arras: the First Battle of the Scarpe (with the capture of Monchy le Preux), the Second Battle of the Scarpe and the Battle of Arleux. Later, from the 31st July to the 12th October 1917, the division, now in Plumer's Army, was engaged in the Battles of Pilckem Ridge, Menin Road Ridge, Polygon Wood, Broodseinde (which Lord Plumer looked on as his most important success), Poelcappelle, and finally the Battle of Passchendaele.

When the German blow fell on the 21st March, 1918, the 37th Division was still in the Ypres sector, but on the 28th of the month it was hurried south to the Third Army in time to stem, in Harper's Corps, the final onslaught at Rossignol Wood. It remained in the IV Corps for the rest of the war, and from the 21st August was continuously engaged. Its battles were: Albert (21st-23rd August), Havrincourt (12th September), Canal du Nord (1st October), Cambrai (8th-9th October), the pursuit to the Selle (9th-12th October) the Selle (22nd-25th October), and the Sambre (4th November), after which it was relieved. During the demobilization period, as the Armies gradually dwindled to divisions and brigade groups, Williams was given command of No. 4 Area, originally that of the Fourth Army, returning home in October, 1919. He had been six times mentioned in despatches and advanced to K.C.B. Declining offers of active employment, he retired, as all officers who could afford to do so did, and settled down to a happy home life, living to celebrate his golden wedding, as he had married in 1889. His time was fully occupied with local activities and work for the Corps. Besides serving on the Council of the Institution, he contributed many reviews to *The R.E. Journal*. These later days were gladdened by the success of his only son (now *p.s.c.*† and a serving brigadier) as cricketer and soldier in the Rifle Brigade

Brigadier General Cecil Hill CB

The enumerations of the services, promotions and honours of an eminent soldier are little helpful to his successors in the Corps except perhaps as an incentive. It is some account of his character and characteristics which may be helpful to them. First and foremost, Bruce-Williams never spared himself and looked to the success of his work, not to any reward that he might receive for it; he was never a striver to climb over the heads of his fellows, but ever ready to give them a helping hand and co-operate for the good of the cause. He abhorred advertisement. He expected much of his subordinates—and got it, the best they could give; for he was at all times thoughtful of them and, as they knew they could rely on full appreciation of good work, all who served under him were devoted to him. One of them, the present *Times* Military Correspondent, writing after his death, has put on record how, when the G.S.O.1 of the 37th Division (now Field Marshal Sir John Dill) was immersed in urgent work during the battle of Arras, his G.O.C. appeared silently at his side carrying a meal on a tray. Captain Falls describes Bruce-Williams as a "striking personality, brimful of energy," who could be severe on occasions, but if he did have to administer a "telling off," quickly forgot all about it.

The other side of his life was fully as successful as his Military career. At his funeral service, his old Division and the various local associations and councils were represented, the Home Guard provided a guard of honour, and Canon MacDermott summing up his life said that "General Bruce-Williams would leave a very great blank in the hearts of his friends and a very great blank among the community which he had served so well. He was a true Christian gentleman, and one who without fail lived up to the motto of the Corps of Royal Engineers, 'Thither Right and Glory Lead.'"

J.E.E.

BRIGADIER-GENERAL C. HILL, C.B.

The death of Brigadier-General Cecil Hill at an Oxford nursing home on December 20th, four days after an operation, was a painful shock to his friends. Although in his 82nd year he had the appearance, manners and health of a much younger man, and many people must have been surprised at realizing his age. He always had a dread of becoming old and useless, and the end came as he would have wished; he was hale and hearty one day, and a week later had gone. Hill was one of the many officers of the Corps of whom it could truly be said that he could have gone anywhere and done anything; and his career opened as if he was destined for a brilliant future. He passed first out of Woolwich, winning the Pollock Medal and Riding Prize; and within four years of receiving his commission in February, 1881, was on active service with Lord Wolseley's Nile Expedition, as a subaltern of the Telegraph Battalion. His father was the late Captain T. Hill, of Romanby, Northallerton, for some time Chief Constable of the North Riding of Yorkshire; and his mother was Frances Miriam Walker, of Maunby Hall, Thirsk, who traced her descent back to King Edward III. Their elder son, Alan Richard, of the Northamptonshire Regiment, won the Victoria Cross in 1882 at Laing's Nek in South Africa within twelve months of Cecil joining the Army.

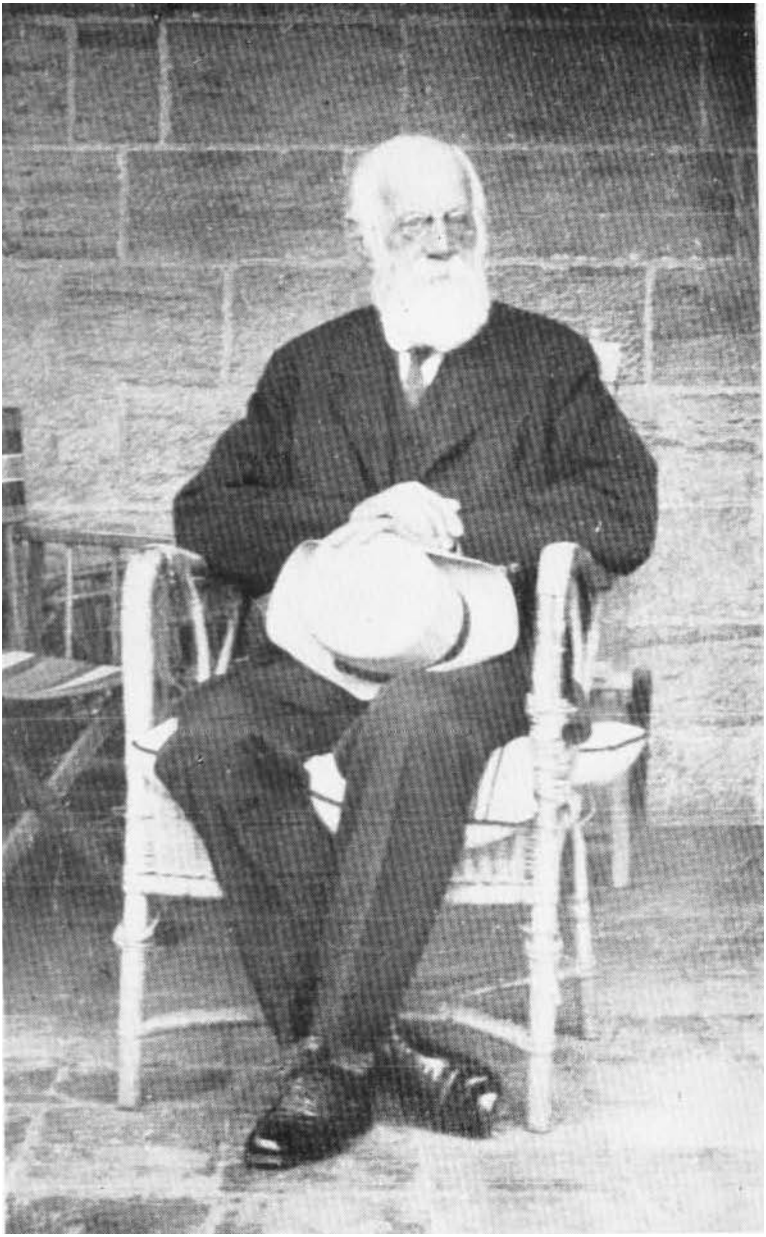
Fate decreed that neither Alan nor Cecil Hill was to rise to the top of the ladder. Thirty years elapsed before Cecil again saw active service, as Chief Engineer of the VI Corps in France. He had been posted to Ceylon for a second tour of duty in 1897 (having already spent five years there between 1886 and 1891), and thus missed the three important campaigns at the turn of the century—Lord Kitchener's Soudan Expedition, the Boxer Rising in China, and the South African War. Hill made no attempt to counterbalance this bad luck and improve his prospects by competing for the Staff College, the goal of most ambitious young officers. With his shrewd and acute brain there is little doubt that he could have added the letters *p.s.c.* to his name in the Army List without much trouble; but he preferred to live his life to the full, doing his work well and indulging his passion for any form of sport on a horse. Ambition had little if any part in his make-up, and he never gave any indication that he regretted his choice. It was a disappointment that he was not promoted Major-General after the last war, in spite of the recommendation of his Corps Commander, General Sir Aylmer Haldane, who always found his work "highly satisfactory." He did not complain, and after his retirement was able to give most of his time and energy to his other passion, love of a garden.

Hill's first station after leaving the S.M.E. was Aldershot, and it was as Chief Engineer there that he ended his career in 1918. In the intervening years he had served at home on the Ordnance Survey at Southampton as a captain, at Bulford as a major, at Cork and Devonport as a colonel, and at Queenstown as Brigadier-General commanding the South Irish Coast Defences. In addition to two tours of duty in Ceylon, already referred to, his foreign service included five years at Gibraltar from 1904 to 1909, possibly the happiest time of his life. During the latter part of this period he doubled the part of C.R.E. with that of O.C. Companies, R.E.—practically equivalent to the command of a battalion, for the Royal Engineers mustered well over 400 on ceremonial parades. Hill, whose experience had hitherto been mainly with the technical side of corps work, was as much interested in the routine of a battalion orderly-room with a regimental staff, as with that of the office of a D.O. or C.R.E.

During these five years on the Rock he was probably more closely associated with his brother Engineer officers than at any other period of his career; and among his numerous contemporaries there, four deserve some notice in this memoir. First, there was the Chief Engineer, the late E. R. Kenyon, who retired as a substantive colonel in 1911, rejoined in 1914 (*at the age of sixty*) as C.R.E. of a division with the rank of Lieut.-Colonel, became Chief Engineer of a Corps in France, and later of an Army, with the rank of Major-General; and, indeed, if rumour spoke correctly, was within an ace of becoming Engineer-in-Chief at G.H.Q. Hill was overjoyed at his old chief's triumphant vindication of the fact that physical fitness is more important than a birth certificate—or at any rate was in those days.

Second on the list was the late G. M. W. Macdonogh, who, after holding the vitally important post of Director of Military Intelligence with outstanding distinction and success, became Adjutant-General to the Forces in 1918, and was at one time considered as being very much in the running for C.I.G.S. Then there was G. E. J. Durnford, ninth member of that family to hold a commission in the Royal Engineers; the year that Hill left Gibraltar, 1909, was the 150th anniversary of the first member of the Durnford family being commissioned, during which long period there had always been at least one, and for six years as many as four, members serving in the Corps. Finally there was W. G. Dean, Regimental Serjeant-Major, until promoted Q.M. and Lieutenant in 1908. Dean's connection with the Sappers may be measured either by the figure 199, which represents the number of years that 7 members of the Dean family (his own generation and the two above it), had served in the Corps; or 377 if the years served by members of his mother's and wife's families are included. Surely the apothesis of a family tradition.

Cecil Hill played a notable part at Gibraltar in maintaining, and increasing, the high reputation held by the Royal Engineers in The Garrison Point-to-Point,



Major Leonard Darwin

regimental polo tournament, and hunting field. He actually came in first in the Point-to-Point in 1909, having been 5th in 1907, and 3rd in 1908; the R.E. won this annual event both in 1908, and 1909, in the latter year for the 10th time since the race was inaugurated in 1891. He was Field Master of the Royal Calpe Hunt, and it was a most unusual event when his familiar figure was not seen with the hounds.

Hill was not long enough at Aldershot during the last months of the war to have left any permanent mark; but it was a source of considerable gratification to him to hold what was then regarded as the blue ribbon of Corps appointments at home. While at Vine Cottage he and Mrs. Hill had the honour of dining with King George and Queen Mary at the Royal Pavilion. It was, perhaps, a paradox that he should have been Chief Engineer at our greatest military centre, for one of his most pronounced attributes was what might be termed his "non-militarism"; it is hardly an exaggeration to say that he was more at home amongst undergraduates from Oxford than he was with a party of generals and colonels. This reticence extended to normal social intercourse, and he took little part in the village life of Sutton Courtenay, where he settled after retiring from the army; but his few friends adored him, and respected his dislike of any form of publicity.

He was not a cricketer, yet followed the national game—whether on the village green or in test matches—with lively interest. Definitely not a churchman in the ordinary acceptation of the word, there were few straighter men. Survived by his widow, formerly Miss Edith Lambert, whom he married in 1893, and his only child, Lieut.-Colonel Vivian Hill, R.A., he joins the Royal Engineers Valhalla. Cecil Hill's place there is an honourable one, but—as he would himself have wished—not unduly prominent.

F.S.G.P.

MAJOR L. DARWIN.

Leonard Darwin was the fourth son of Charles Darwin, the great naturalist. Born in 1850 he completed his education at the Royal Military Academy, Woolwich, and entered the R.E. in 1871 in the rank of Lieutenant. Among the staff of the S.M.E. in 1871 was Captain W. de W. Abney, the Assistant Instructor in Chemistry and Photography, who among many other inventions had designed a method for observing photographically the transit of Venus which was due in 1874. Darwin was one of the young officers selected by Abney to accompany him on this expedition to New Zealand. On completion, he was ordered abroad for service at Malta in 1875, but was brought home in 1877 to succeed Abney at the S.M.E. where he continued the work of his predecessor in the development of the photographic school. He remained at Chatham till 1882 when he was again selected to photograph a transit of Venus, this time in Brisbane, Australia. The same year he entered the Staff College, taking the first place in the entrance examination. He was promoted Captain in January, 1883. On completion of his two years at the College he went to the War Office, and in July, 1885, was selected as Secretary of a very important Committee, which was assembled under Lord Sandhurst to investigate the strength and composition of the Corps of Royal Engineers. At this time the Corps numbered 452 officers and 5,470 other ranks, but there were demands for large increases for the Submarine Mining Service and for the Field units. As a result of an investigation which lasted for twelve months additions were made to the Corps of 126 officers and 1,748 other ranks. The Secretary of such a Committee has very important duties in the collection of evidence and in suggesting the names of officers to be examined and Darwin's conduct of the whole business marked him out as one of the most promising of the younger officers of the Corps.

After this, Darwin was employed in the Intelligence branch of the War Office till 1890, receiving promotion to Major in April, 1889. On leaving the War Office he retired from the Army to take up political life and in 1892 he was elected to Parliament as a Liberal Unionist for the Lichfield Division of Staffordshire, which he held till 1895 when he lost his seat at the General Election of that year. He tried again unsuccessfully the following year. He had many other interests; he was President of the Royal Geographical Society from 1908 to 1911, President of the Eugenics Education Society from 1911 to 1928, Chairman of the Bedford College for Women in the University of London from 1913 to 1920 and throughout the 1914-18 war was Chairman of the Professional Classes Relief Council. He was an Honorary Doctor of Science of Cambridge.

He published a work on *Bimetallism* in 1898, on *Municipal Trade* in 1903, and on *The Need for Eugenic Reform* in 1926.

He will be best remembered for his work as President of the Eugenics Education Society. He has been described as the founder of sane views on population and society and his book on eugenic reform will probably be long accepted as the standard presentation of the case for eugenics; moderate in temper, it was based on sound learning, and did much to raise its subject from a position of pseudo-science, the hobby of a few cranks!

Darwin was twice married; his first wife, the daughter of Mr. G. R. Fraser, died in 1898, and in 1900 he married for the second time Charlotte Mildred, daughter of the late Mr. E. Langton, she died in 1940. Darwin himself passed away at Cripps Farm, Forest Row, on 26th March, in his 94th year.

W.B.B.

ORGANIZATION AND EXECUTION OF ENGINEERING WORK.

ASSUMING general agreement upon the importance to the engineer of competency to deal with the organization and economic aspect of construction, an attempt has been made to propose methods by which the student may be educated and to suggest that the present curriculum shows gaps which could be filled by drawing on the wealth of accumulated knowledge and experience of the engineering professsion. On the organization side, a description has been given of a military system, but there is nothing essentially military about it. It might equally well be called a Euclidian system, as it is merely a clarification of the mind, firstly to decide exactly what the task is and secondly, by logical reasoning, considering all the aspects of the problem, to lead up to a definite outline plan. The outline plan having been arrived at, the detailed plan is prepared, showing the requirements of labour and material and the time at which they are required. This plan, drawn up before work is started, will produce an ordered and balanced programme forming the basis of the work and ensuring even progress from beginning to end.

Emphasis is laid upon the necessity of introducing the economic aspect to the student at the very beginning of his career, with some suggestions of the methods by which it can be done. The young engineer must be made to recognize that the financial side is not only an essential part of his duty, but also that it adds to his armoury another weapon which will enable him to reassure himself that the work is progressing according to plan and that he is not heading for disaster either in time or money.—(Major-General C. J. S. King, C.B., C.B.E., M.INST.C.E., in a Paper read before the Institution of Civil Engineers.)

All Reviews of Books on military subjects are included in the provisions of K.R. 547(c) *1940*.

BOOKS.

(Most of the books reviewed may be seen in the R.E. Corps Library at Brompton Barracks, Chatham.)

PRACTICAL ENGINEERING PROBLEMS AND THEIR SOLUTION.

By F. H. Higgs.

(Longmans, Green & Co. (48 pp., 7" × 4¾"). Price 1s.)

The title of this book is very misleading. It consists simply of a disjointed series of extracts from elementary text books on Mathematics and Drawing.

It starts by explaining decimal fractions, plane geometry is reached on page 15 and trigonometry on page 22. One chapter of about six pages is devoted to what is called "developments" but it really explains how to calculate the total length of sheet metal required for a channel or other curved form of given dimensions.

There is one chapter of three and a half pages on drawings and the book concludes with a chapter of one and a half pages on "limits" and some eight tables of S.W.G. plate sizes, drills, etc.

The book appears to be an attempt to produce something to help the many amateurs at present employed in engineering workshops, but it is feared that the treatment is inadequate for its purpose. W.M.

ENGINEERING MATERIALS, MACHINE TOOLS AND PROCESSES.

By W. Steeds.

(Longmans Green & Co. 336 pp., 357 illustrations. Price 16s.)

With the large increase in the number of people employed in engineering workshops at the present time there has naturally been produced a great number of textbooks of this type to help them, but this is certainly one of the most lucidly written, and it is right up-to-date (1942).

The author is a practical engineer of considerable experience and will be recognized as one of joint authors of that excellent book *The Motor Vehicle* so well known to engineers interested in mechanical transport.

The book can be divided into two parts, the first three chapters (69 pp.) being devoted to the properties, testing and inspection of engineering materials and the rest of the book to manufacturing methods, including chapters on welding, press-tool work and spinning, plastic moulding, milling and broaching.

The book gives the student and engineer a very good background of general knowledge and there are a large number of references to help them to pursue any subject of special interest.

The treatment should prove useful for students working for membership examinations of the engineering Institutions and for National Certificates in Mechanical Engineering. W.M.

MILITARY SCIENCE TO-DAY.

By Colonel D. Portway, T.D., A.M.INST.C.E., R.E.

(Oxford University Press. Price 4s. 6d. net.)

This is a new edition of Colonel Portway's book, which has already been reviewed in *The R.E. Journal* in September, 1940. In a *Note on the second edition* the author explains that with the violent fighting that succeeded the long stalemate in France in 1939-40, many new applications of Military Science came into being, but the changes made in the book are not considerable, although it was necessary to re-write part of the chapter on Tactics and make small amendments in other chapters. It will be recognized that in time of war it is impossible to include details of such confidential subjects as radio-location, anti-aircraft improvements, bomb disposal and the like, but, in spite of this, this well-illustrated book contains abundant information which cannot fail to be of interest both to military readers and to the general public.

F.E.G.S.

I. I. POLZUNOV.

THE WORK AND LIFE OF THE FIRST RUSSIAN HEAT-ENGINEER.

By V. V. DANILEVSKY.

(Published in Moscow and Leningrad by the U.S.S.R. Academy of Science Press—1940.)

Few people, including educated Russians, have heard of the subject of this memoir, Ivan Ivanovitch Polzunov, who according to the author should rank with Hero of Alexandria, Leonardo da Vinci, Denis Papin and James Watt as one of the greatest technical geniuses of their age.

Born in 1728, the son of a soldier of Ekaterinburg (now called Sverdlovsk) and sprung from the lowest Russian social stratum, Polzunov did not receive a higher education. Nevertheless by hard work, stubbornness, method and intense keenness for his ideals, he managed to equip himself with the necessary knowledge not only to carry out theoretical investigations, but also to apply them practically. In 1763 he affirmed that in order to lighten the labours of coming generations, it was essential to use heat as the power for actuating machinery. Although in that period of feudal serfdom in Russia, and owing partly to his early death at the age of 38 years, he did not realize his dreams, nevertheless he was the first technician in history to instal a steam-engine for providing the motive power for the machinery in a factory.

Knowledge of the extent of his work has only recently been acquired after seven years' research among the archives of the Altai, Novosibirsk, Sverdlovsk and Leningrad.

In 1743, after finishing school at Ekaterinburg, Polzunov was employed as an apprentice mechanic, at a maximum salary of 7 roubles per annum, for five years in factories in the Urals. Transferred in 1748 to the silver, lead and copper mines in the Altai, some 300 miles South of the town of Obi, he spent ten years in this region chiefly at Barnaul, in acquiring experience in mining engineering and construction.

On the 1st January, 1758, he was sent to Petersburg with a report on the working of the Kolubano-Voskresenky mines together with the output of gold and silver mined in 1757. This amounted to 65 lb. of gold and 8,845 lb. of silver. The journey of 3,000 miles by sleigh via Moscow took 64 days. The party consisted of Polzunov, Capt. Shirman and an escort of 12 dragoons, and the expenses of the trip totalled 924 roubles, about £93. The advent of the treasure at the Capital was hailed with joy by the Empress Elizabeth Petrovna and her Finance Minister, as their exchequer was as usual in low water.

Returning to Siberia, Polzunov carried on his work at the mine, continuing his investigations and experiments, with the cordial support of the head of the administration.

In April, 1763, he submitted a report on the inadequacy of the existing methods of working the mining plant, together with a description and plans of a steam-engine to supply the motive power.

It is difficult at this date to ascertain what sources of information were at Polzunov's disposal, but it is probable that he had access to Schlatter's work on mining engineering, published in 1760, and Jacob Leupold's volumes on mechanics, published at Leipzig in 1724 and 1725.

Presumably, Polzunov from 1763 onwards was busy building and installing his new engine, because in December, 1765, a full description and working drawings of the engine were sent to Petersburg. The originals were found in the Leningrad archives in March, 1936.

The drawings (seven of which are reproduced in the book) show a two-cylinder steam-engine, working a beam, which alternately inflates and depresses a pair of bellows, and sends a stream of hot air into the smelting furnaces.

The engine has the following features :—

(1) Device for alternate entry of steam into the cylinders.
(2) Safety valve.
(3) Automatic feed.
(4) Test cocks.
(5) Pipe for filling boiler before starting work.
(6) Pipe for blowing through the boiler.

From the colours in the drawings it is presumed that the materials used were as follows :—

Copper for the boiler, cylinders, pistons, valves, pipes, cocks, etc.

Iron for the chains, connecting-rods, pump-casings, and the moving parts of the mechanism.

It must be remembered that to assist him in his work, Polzunov had only a couple of apprentice-mechanics and some peasants.

He was not only the inventor, but the scientist, constructor and designer of all the details of the engine and buildings—in fact the guiding spirit in producing and working the new plant.

Polzunov was not fated to see the full results of his work, as he fell seriously ill from consumption, and on the 21st April, 1766, sent a petition to his superiors to remit the 400 roubles reward for his invention granted to him in 1763 by Catherine the Great. The money was handed over to him immediately, and prior to his death on the 16th May, 1766.

At the time of his demise, his plant was in working order and continued to function till November 1766, when it stopped, and no attempt seems to have been made to repair or remodel it. It remained in position till 1780.

Returns, however, show that the output from this plant more than trebled between 1760 and 1766, a tribute to the drive and organizing power of Polzunov.

The author attributes the lack of interest in the invention to the reactionary Cabinet of the Tsarist *régime*, though the Empress had personally approved the plans, and also to the enormous man-power available in Russia. It is also probable that the lack of knowledge and experience in the strength of materials—Polzunov himself was doubtful about the ability of his boiler to withstand the pressure of steam—led to many breakdowns, and delayed the adoption of steam in place of man and water power.

This book, of 440 pages, is well printed and profusely illustrated, and all statements are supported by references to the archives. It contains in addition a lengthy summary of the contemporary inventions of scientists of other lands. As, however, it is printed in Russian, the memoir can have but a limited appeal in this country.

C.G.F.

CORTEZ' TANKS.

When, in 1520, Cortez was obliged to evacuate the city of Mexico "The chief embarrassment was as to the time and manner in which it would be expedient to evacuate the city. The best route seemed to be that of Tlacopan (Tecuba). For the causeway, the most dangerous part of the road, was but two miles long in that direction, and would, therefore, place the fugitives, much sooner than either of the other great avenues, on terra firma. Before his final departure, however, he proposed to make another sally in that direction, in order to reconnoitre the ground, and, at the same time, divert the enemy's attention from his real purpose by a show of active operations.

"For some days his workmen had been employed in constructing a military machine of his own invention. It was called a *manta*, and was contrived somewhat on the principle of the mantelets used in the wars of the middle ages. It was, however, more complicated, consisting of a tower made of light beams and planks, having two chambers, one over the other. These were to be filled with musketeers, and the sides were provided with loopholes, through which a fire could be kept up on the enemy. The whole advantage proposed by this contrivance was to afford a defence to the troops against the missiles hurled from the terraces. These machines, three of which were made, rested on rollers, and were provided with strong ropes, by which they were to be dragged along the streets by the Tlascalan auxiliaries.

"The Mexicans gazed with astonishment on this warlike machinery, and, as the rolling fortresses advanced, belching forth fire and smoke from their entrails, the enemy, incapable of making an impression on those within, fell back in dismay. By bringing the *mantas* under the walls of the houses, the Spaniards were able to fire with effect on the mischievous tenants of the *azoteas*, and when this did not silence them, by letting a ladder, or light drawbridge, fall on the roof from the top of the *manta*, they opened a passage to the terrace, and closed with the combattants hand to hand. They could not, however, thus approach the higher buildings, from which the Indian warriors threw down such heavy masses of stone and timber as dislodged the planks that covered the machines, or, thundering against their sides, shook the frail edifices to their foundations, threatening all within with indiscriminate ruin. Indeed, the success of the experiment was doubtful, when the intervention of a canal put a stop to their further progress."

From Prescott's *History of the Conquest of Mexico* Book V, Chapter II.

MAGAZINES.

THE INFANTRY JOURNAL.

(*January*, 1943).—*Sevastopol and Verdun*. By Lieut.-Colonel P. W. Thompson.

The writer draws a comparison between the German attacks on Verdun in 1916–18 and those made on Sevastopol during the present war. The article is in two parts, of which the first deals with Verdun.

The Verdun of 1914 (not of 1916) represented the last word in the art of fortification. At that time the fortress was the northern anchor of the great defensive curtain that faced the German border for fifty miles, extending to the southern anchor at Toul. Between the fortresses of Verdun and Toul were numerous " detached forts," so located as to lead the attacker into action in the corridors between them, and to subject him to flank attacks carried out by forces massed in the rear.

The chief element of the Verdun fortress was the ring of forts (Douaumont, Vaux, etc.) and intermediate works (Froideterre, Thiaumont, etc.) spaced at an average distance of about five miles from the citadel in the city. In the north-east sector, where the weight of the German attack was to fall, this ring of major works occupied the dominating heights which formed the dividing line between the valleys of the Meuse and the Woevre. There was another ring of supporting works between the city of Verdun and the outer ring.

Verdun had been the pivot round which the Allied lines had bent during the autumn of 1914. Up to the end of 1915 it had projected like a breakwater into the German front, and quiet position warfare had become the order of the day.

In January, 1916, the Germans decided to launch a general attack on the fortress, and to capture it after subjecting it to an overwhelming artillery bombardment with the heaviest guns. While the Germans were making their plans and preparations, the chief thing that the French had done was to undo the work of past decades. They had converted the great fortress of Verdun into a " fortified region," which meant simply a position organized with field fortifications. Under that conception, Vaux, Douaumont, and the other great structures of steel and concrete were merely white elephants. The French proceeded to abandon them and to replace them with trenches and dug-outs and barbed wire entanglement. The garrisons and supplies of all kinds were withdrawn from the works; the guns flanking the intervals and the machine-guns in the turrets were removed. Completing the thorough job of declassing the fortress, the French engineers were ordered to prepare all the principal works for demolition.

The conversion of a great fortress into a " fortified region " was based on the same considerations as those which had induced the Germans to bank so heavily on the power of artillery. In short, the French followed the Germans in the conclusion that the gun had won the age-long fight with the fortification, and they (the French) implemented their belief by declassing Verdun and other fortresses.

The " considerations " in question were the result of certain developments of the first few months of the war. In those opening months Liège, Namur and Antwerp in Belgium, and Kovno and Novogeorgevsk in Russia, had fallen after a few days' bombardment. Considering these facts (and ignoring the relatively minor damage inflicted on the well-constructed works by some bombardments and the complete failure of others) the French and German master minds stirred up a revulsion against the use of permanent fortifications.

Late in January the Germans began to move their special assault army into position (the fifth, consisting of five corps, under the command of the Crown Prince). The attack opened on the 21st February. The opposing forces in the sector attacked were as follows. The Germans had eight well-trained rested divisions to throw against two French divisions, one of which had just taken its place in the line. The Germans disposed of nearly 200 batteries of artillery, as against 160 French batteries. Their guns were, on the whole, of heavier calibre, and they were better supplied with ammunition.

At 0812 on February 21st, the great bombardment, perhaps the greatest of all time, opened up, and continued for nearly nine hours. The rate of fire increased as the morning wore on. The heavy calibre guns worked over the entire French position, paying special attention to the forward edges of the woods, in which the advance positions were thought to be. The bombardment continued until 16.50, when, expecting to find the French garrison completely annihilated, the Germans launched their assault, anticipating an easy success. But they were terribly disappointed. Not only were they met by a severe machine-gun fire from the woods as they crossed no-man's land, but they found the French positions essentially intact, and the fighting power of the defending garrisons unimpaired. The positions consisted in general of trenches, obstacles, and cut-and-cover machine-gun emplacements. There was nothing unusual about the trenches, but the belts of obstacles were unusually wide and strong. A field of fire, from 60 to 100 feet wide, had been cleared in front of the obstacles. The machine-gun emplacements, built up of logs and earth, set deeply in the ground, had, for the greater part, survived the bombardment unharmed. They had been skilfully sited and were effectively concealed amongst the trees.

Against this wall of obstacles and machine-gun fire the Germans had no good answer. All they had were their rifles, and bayonets and flame-throwers when got to close quarters. In consequence, the first day's assault resulted in negligible gains.

The attacks were renewed, day after day, for eight days. We are given an account of a typical day's fighting, which shows how little the Germans gained at an enormous cost of men and materials. At the end of eight days the Germans were at the point of utter exhaustion, and the attack was called off.

It is true that they had, by a fluke, succeeded in capturing Fort Douaumont, finding it practically unoccupied. This woke the French up to the fact that the forts which the French had abandoned were, in fact, able to stand up under bombardment and could serve their intended purpose of forming the backbone of the defensive system. In later weeks and months the French sacrificed almost everything in order to get Douaumont back, and, at the same time, they rushed to get the other forts back in commission.

The end of the first eight days at Verdun marked the end of the dream that guns, of sufficient weight and in sufficient number, plus infantry with rifles, could smash through anything and carry any field. Eight months later the Germans broke off the Verdun venture.

(February, 1943).—Sevastopol and Verdun. Part II. By Lieut.-Colonel P. W. Thompson.

The second part deals with Sevastopol.

As a fortress Sevastopol was a Verdun, modernized, strengthened, and spread over half again as much space, and with terrain even more rugged. The approaches to it from the north, east and south, are over rough wooded hills; changing to bleak rocky heights within five or six miles of the city, practically barren of vegetation.

One controlling feature, destined to play an important part in the assault, is an inlet known as Severnaya Bay, some 3 miles long, 1,000 yards wide at its mouth, and tapering to the mouth of the Chernaya River. Bay and river together divide the Sevastopol area into two approximately equal parts. The general Sevastopol area forms a peninsula, jutting into the Black Sea. Obviously a good deal was to depend on who controlled that sea.

The virtue of the cut-and-cover emplacements of Verdun had been their inconspicuousness. The virtue of the minor works and bunkers of Sevastopol was in their multiplicity and their sheer strength. While the Verdun works were dug out of the clayey earth and covered with six-inch timbers, the Sevastopol bunkers were hewn out of the virgin granite, and made of reinforced concrete and armour-plate.

The backbone of Sevastopol's strength was in the line of great forts occupying the heights approximately 3,500 yards north of Severnaya Bay—forts with the names of *Cheka, Maxim Gorki, Molotov, Stalin,* etc.! These were the Sevastopol counterparts of Douaumont and Vaux, but they were individually stronger than the French forts and also more numerous. Once the Soviets realized the possibility of the Germans reaching the Crimea, nothing was allowed to stand in the way of making the north Sevastopol forts the strongest of their kind in the world.

An example is Fort Maxim Gorki. It was situated far out to the front, on a hill rising 50 feet sheer above the general plateau. Originally designed for coastal protection, it was converted into a fort capable of all-round resistance against ground attack. In general it resembled the major works of the Maginot system.

All the major works were mutually supporting, and, between and around them, were myriads of smaller works and obstacles. Besides the fortifications proper, the hills were honeycombed with tunnels and shelters, hewn out of the rock.

On the Black Sea the Russians disposed of a considerable fleet (one battleship, one carrier, four to six cruisers, an unknown number of submarines, destroyers, etc.), but the fleet was to have little influence on the course of events. In the air the Russians were woefully weak; they had only about 100 planes, and one or two air-fields.

The fall of Sevastopol was really the final phase of the self-contained campaign in the Crimea. That campaign began when the German-Rumanian army of General von Manstein forced the defences of the Perekop peninsula, the narrow neck of land which connects the Isthmus of Crimea with the mainland. That was in the September of 1941. There followed a methodical advance down to the Isthmus, leading by mid-December to the complete land-encirclement of Sevastopol.

With the fortress contained and the peninsula under control (the remaining Russian forces had withdrawn across the Straits of Kerch), the Germans turned their attention to their communications. They collected a mass of their heavy and heaviest calibres; some of it even dwarfed the 420 mm. stuff of Verdun. It also included some equally formidable railway pieces.

During the first five months of 1942 the Russians tried to re-establish themselves in the Crimea by means of a landing at Feodosia, and by numerous commando-type landings all along the coast-line. The Germans were compelled to dispose of these menaces before they could begin a systematic attack on Sevastopol.

During the latter half of May all was in readiness. The Axis attacking forces consisted of the Eleventh Army of General von Manstein, the Close-Support Air Corps of General von Richthofen, and a mixed fleet of German, Italian and Rumanian speedboats and submarines. It is conjectured that Richthofen had as many as 1,000 aeroplanes.

The German plan for the assault was to launch the main effort on the stronger line of forts to the north of Severnaya Bay. It began on June 2nd, in the form of a terrific bombardment, which went on for five days (as compared with nine hours at Verdun). The Verdun bombardment had been directed at an area in which the locations of enemy positions were unknown. The Sevastopol bombardment was directed at point targets, at specific critical works, the exact locations of which were known through air-photos and month-long ground reconnaissance.

At the end of the fifth day of bombardment: *i.e.*, at 0300 hours on June 7th, the German assault teams moved out. It was found that the net result of the bombardment had been much the same as at Verdun; the defences had not been flattened out by heavy artillery. But there the similarity ended. Reconnaissance had been almost complete. The use of the flame-thrower, formerly a surprise weapon, had proved most effective. The German storm trooper had been fully supported by infantry howitzers, anti-tank and A.A. guns, and, above all, the Germans had secured absolute mastery of the air. The Russian air force could do practically nothing to counter the incessant German dive-bombing.

The progress of the assault was, roughly, as follows:—On June 2nd the artillery bombardment began, followed by the infantry assault on the 7th. Fort Stalin fell on the 14th, Fort Maxim Gorki on the 18th, and Fort Lenin on the 20th. The whole of the area north of Severnaya harbour had been mopped up by the 20th.

At this stage of operations the Germans brought in two new factors. With two Rumanian and, perhaps, four German divisions which had been engaged in holding off attacks south-east of the fortress, they made a full-scale attack from the south-east. At the same time they sent a force across Severnaya Bay in motorized storm-boats. The crossing was accomplished by daylight under cover of a dense smoke-screen.

Meanwhile the German-Rumanian attack against the heights of Sapun, S.E. of the fortress, was making headway. On July 2nd the attackers drove into the eastern outskirts of the city. Sevastopol was doomed. The remnants of the Russian army, 70,000 in number according to the German account, withdrew on to the narrow peninsula of Cheronnes, where it was subjected to the most terrific bombardment. The survivors surrendered on July 4th.

It is interesting to compare the assaults on the two great fortresses of Verdun and Sevastopol and to draw what lessons we can from them. Sevastopol was, inherently, the stronger of the two. But Sevastopol was, to all intents and purposes, an island, isolated from its bases. It had to go through the fight with such resources, both in men and munitions, as were in the area when it was invested in February. Verdun practically never suffered for lack of men or ammunition; each day saw a further drain on the resources of Sevastopol. The Russians were thus precluded from carrying out any counter-attacks.

In the 25 years that elapsed between Verdun and Sevastopol it was realized by the Germans that artillery support for an infantry assault is as necessary as ever, and also that ways and means must be found to give assault troops artillery support throughout their actions. Thus light portable flat-trajectory guns became a part of the assault team and accompanied the forward elements of the team into battle.

For close combat there is little difference between the assault trooper's equipment of 1916 and that of 1942, beyond a general improvement in the weapons themselves and the technique of their use.

The extensive employment of air-photos makes all the difference in reconnaissance work in these two periods. At Verdun air-power was in its infancy. At Sevastopol it was responsible for the completeness of the pre-battle reconnaissance, for the blocking of the Black Sea route, in the preparatory bombardment, and in all phases of the battle.

In radio work and field telephone lines progress must have been as remarkable as that in any other field.

A.S.H.

ERRATA.

In *The R.E. Journal* for March, 1943, on page 69, line 25, for "*Combatant* Army," read "*Combatant* arm." Page 72, line 31, for "experimental within an area," read "experimented with in an area." On page 73, 11 lines from foot of page, for "uniting" read "limiting."

REVUE MILITAIRE SUISSE

Sept. 1942)—*Idées de manœuvre du haut commandement français.* By Capt. E. Bauer.
This instalment gives us the disposition of the French forces on the eve of the German onslaught of May 10th, 1940. The author criticizes this disposition and concludes that the French disasters were the logical outcome of the initial arrangements of General Gamelin and his staff at Vincennes. The whole Allied force amounted to 107 divisions, including 10 British and 2 Polish, the latter in the process of formation. But of these 107, only 67 were actually available for the first shock of battle. More than a fourth of the Allied forces were in reserve.

General Gamelin, says the author, risked all the fate of France on a first encounter battle, in the hope of a quick victory. The troops at the disposal of General Billotte, who was to meet the principal mass of German armies, were too few. He had under his orders the First, Second, Seventh and Ninth Armies and the British Expeditionary Force: in all 32 infantry divisions, 3 light mechanized divisions, 4 light cavalry divisions and 2 mounted brigades.

The Second Army Group, under General Prételat, comprised 3 armies: the Third, Fourth, and Fifth, totalling 7 corps or 26 divisions. This Group was charged with the defence of Lorraine and Alsace between Longwy and Selestat, and it had the protection of the Maginot Line, to which were allotted an additional 8 divisions.

The Third Army Group, commanded by General Besson, had the Eighth Army of 5 divisions and covered the defence of Upper Alsace between Colmar and the Swiss frontier.

Thus the quiet fronts of Alsace and Lorraine with the Maginot Line were allotted 41 divisions or their equivalent, while General Billotte in the unfortified north had only 39.

In spite of the dangerous task allotted to Giraud and his Seventh Army, only 7 divisions were available for him, while Bourret on the quiet sector Bitsche-Selestat, had 9. General Corap had only 7 divisions with which to hold the Meuse from Sedan to Namur, 90 kilometres, while Condé had 10 divisions on the Maginot Line between Boulay and Longuyon, some 70 kilometres. These disparities point to a serious misunderstanding of the situation. The French General Staff cannot be lightly accused of incompetence; its reputation in European circles ran high. But some grievous rot seems to have set in which hypnotised its leaders. It was some very serious shortcoming which brought so overwhelming a disaster in so short a time.

(*Oct.* 1942.)—*Commentaires sur la guerre actuelle.* The battle of Stalingrad, at the time of writing, October 20, continued to draw the attention of the world. Although the rest of the immense eastern front was not inactive, the *communiqués* dealt chiefly with the incidents of this or that block of houses in the grim struggle for Stalingrad.

On October 9th, Hitler had announced that the offensive against the city was about to stop. The strategic object had been attained; the complete conquest of the place would now be for the heavy artillery.

But the pause only lasted three days. The assault was renewed with as much ferocity as ever, and regiment after regiment of infantry was hurled into the furnace. Hitler's prestige was at stake. He had announced that he could take the city when he wanted. It would be taken; of that the German nation could be assured.

But von Bock was removed and succeeded by von Hoth. In the north, the Russians attempted to relieve Leningrad by an attack on Schlusselburg, but they were driven back. The Germans, however, had not broken up the Russian Armies. They may have thought that they had won their strategic object at Stalingrad, and boasted that they had done so, but was it not possible that they would have to withdraw something from the east to meet the British in the Middle East? The Volga and the Caucasus were their objectives for 1942.

(*January,* 1943.)—*Commentaires sur la guerre actuelle.*
The Russian armies in the autumn of 1942 had been pushed back on their communications to such an extent that it was becoming very difficult for them to shift their reserves from place to place. Had Stalingrad fallen, their case would have been very much worse. Hence the prolonged violence of the German attack, and the stubborn and heroic defence. But in spite of their handicaps and their heavy losses of men and material, the Russians began a counter-offensive on a larger scale than they had ever attempted. A series of well-timed and consecutive attacks throughout December and January gave them back much of the territory lost in the autumn; by the end of January the German hold on the Caucasus slopes had been loosened. The Russian plan was on a vast scale, and if the thaw had not set in unusually early it is likely that much of the Ukraine might have been liberated by February. By the end of January, the Germans were already in a delicate situation. Their army at Stalingrad was surrounded, and they had to do what they could to supply it by air.

In North Africa, the thunder-bolt of the Allied descent had been followed by a rapid stabilization. While the Allies had immence distances to cover, the Axis Powers had all the advantages of shorter supply routes and nearer bases. The political entanglements among the French were also contributories to the difficulties of the Allies. A gallant attempt by the British First Army to snatch Tunis fell short of success, but there were insufficient forces to ensure it, and the British had to fall back.

Meanwhile, in Tripolitania, the Eighth Army was hustling Rommel back from one position to another. Clearly Rommel was seeking to gain time, but his plan was to get back to Tunis to join forces with von Arnim.

The French column coming across from Lake Tchad had achieved a fine performance; it was now joining in the combined operations against Rommel.

W.H.K.

JOURNAL OF THE UNITED SERVICE INSTITUTION OF INDIA.

(October, 1942.)—(*Received in this country about the middle of March,* 1943.)

What shall I do next? is a question put to every C.O. The author divides his subject into the three branches of training, namely technical, physical and mental. One would like the article longer, in order to contain some more concrete suggestions, but one of profound importance is the choosing of a very good man as Q.M., to mitigate the discomfort inevitably caused by the rapidity of modern war.

Bombing; the Worm's eye view will appeal to many sufferers. There are many useful suggestions. In a slit trench don't lean hard up against the side—a near miss may injure your back; again, the positions of H.Q. are as often as not given away by the surround of slit trenches. There are some amusing anecdotes, notably of a Burmese boy who said of his first raid that it was a most enjoyable sight, and that he hoped to see one every day.

The History of Flying in India dates from 1913, when an Indian Flying School was started at Sitapur, U.P. On the outbreak of war in the following year, the school was broken up and the machines sent overseas, but in December, 1915, No. 31 Squadron of the R.F.C. came to India and has been there ever since. Their first active service was against the Mohmands in October, 1916. The story is continued to date. Captain (now Brigadier) Broke-Smith is mentioned as the first officer on the Indian establishment to get a pilot's certificate.

A Combined General Staff is a collation of the views of distinguished officers, quoted *verbatim*. Sir Edward Grigg wrote a letter to *The Times* representing that the daily meeting of the three Chiefs of Staff was not enough, since each was a hard-worked man whose task in running his own service was sufficient. What was wanted was a C.C.G.S., not a minister, and whether sailor, soldier or airman mattered not so long as he had a thorough knowledge of the working of the other services. These views are supported by a leader in *The Times*, by Sir Fred. Sykes, Lord Hankey, Lord Swinton, Lord Trenchard and many others. The *Journal* itself produces no comments, stating merely in the Editorial that the object of the article is to keep its readers aware of latest ideas and developments on the subject.

The War on the Salvage Front tells of efforts being made in India to-day. An interesting note is that, in the last Great War, blood from slaughtered animals was used instead of linseed oil in the manufacture of paint.

Some articles of a less serious nature deal with *Regimental Nicknames* and *Sea Trout Fishing*, but *After the War* deserves serious consideration from all about to retire. Fifty is by no means too great an age to begin a new career, and the author, apparently with experience, points out the advantages of farming.

The author of *Our Military Man-power Problem* complains of the way in which battalions left in India are constantly milked of officers and men for drafts for the various fronts. His remedy is "drafting battalions" to which men will be sent after the training battalion stage, whence they will be sent to active battalions in India or overseas as demanded. Thus, an active battalion in India need never fear the loss of draft after draft and can concentrate on its preparation for war.

Sidelights on Gurkha Recruiting emphasizes the great contribution being made by Nepal to the Allied war effort. In particular many Brahmans normally precluded by caste from military service, try to enlist, and sometimes succeed, by claiming to belong to a lower caste.

Commandos and Waziristan explains itself. Could commandos be trained to act transfrontier as they have done in France and Libya, a good many of our problems could be solved. The main difficulty is that it would generally be necessary to leave our dead and wounded out, and the author suggests a proclamation of a large reward for persons brought in.

What shall we Talk? is a plea for teaching Esperanto to British and Indian ranks. Though pleading eloquently, the author has failed to convince the Secretary to the Board of Examiners, who in a postscript states the remedy for Babel to be in more attention by Britishers to the study of the various Indian languages *after* the exam.

Finally, a letter on marching records of the Indian Army tells of a battalion, apparently of the Burma Rifles, which during the 1942 campaign marched 1,200 miles in just under four months. Generously the author gives the palm to a unit other than his own Mountain Battery, which covered 1,800 miles during that time.

(*January*, 1943.)—The Editor makes the valuable suggestion that regimental and other war memorials in India, should be, instead of monuments, " scholarships in agricultural colleges, courses in military schools " and so on, and that details should be worked out now and not left until after the war.

The Qualities of a Leader is a subject often treated of, and the author acknowledges his debt to F.M. Sir A. Wavell and others. The article is good reading " Leadership is not a privilege ; it is a duty and trust " is an admirable summing up.

A Cavalryman in the Crimea consists of extracts from the letters of Major Phillips of the 8th Hussars, including one written two days after the charge at Balaclava, in which he took part. The collection ends with sad accounts of the sufferings of the horses which had taken part in that battle.

Junglecraft is so full of interest that nothing less than a reprint would be of much use as a review. The uses that can be made of bamboo are almost numberless ; illustrations are given of cooking vessels made therefrom, of an efficient obstacle called *panji*, and of a method of making fire by rubbing two bamboos together.

Training ; a Post-mortem discusses pre-war methods in the light of our reverses. The author pleads for more initiative on the part of junior leaders and comments on the deadening effect of most tests on this desideratum. One concrete suggestion is " fewer umpires on manœuvres " pointing that many a situation could be solved by a conference between the opposing leaders on the spot ; this would, however, mean that each side would have to give away its strength and dispositions to the enemy, and so subsequent operations would be considerably hampered.

Public Relations deals with the work of the Inter-Services directorate of that name. Its tasks are many and difficult. " The writing of articles and paragraphs for newspapers, organization of Press Conferences, initiating and carrying out of publicity schemes, provision of broadcasts, films and lectures, conducting of Press representatives to see the Services, either on active operations or at war stations, and, last but by no means least, Press Censorship." These activities must be so co-ordinated that no one of the three services feels itself slighted, and at the same time can be assured that its security demands have been met with. Its observers are at times exposed to as much risk as front-line troops—one of them during the attack on Sidi Omar stationed himself 400 yards from the German position and watched the attack successfully carried out by the Royal Sussex and 1st Punjab Regiment. He then streaked off to Cairo, and returned next day with copies of the *Egyptian Gazette* blazoning the full story—a particularly gratifying reward for the troops which had taken part in the battle.

An Introduction to the Red Army traces the evolution of the Russian forces from the last great War to the present one. Stress is laid on the gradual abandonment of the internationalism of the early Soviet army, and the change to patriotism as its leading motive. The efficiency of the army has gone hand in hand with the industrialization of the country and the credit for both goes to Joseph Stalin.

The Hurs is an account of a side-show in Sind in 1941–42 against the dacoits under Pir Pagharo, at one time numbering 5,000 men. The scene of operations lies between the Indus and the Rajputana desert, and embraces the swamps round the Nara River. It is interesting to note the reappearance of M.I., the mount being any nag picked up locally. The Hur on foot can outpace a riding camel, and that is saying a good deal.

Soldiering in Ceylon describes conditions to-day in the island, where British troops, some with three years fighting in the Western Desert, Indians, East Africans, and of course Sinhalese units, are quartered, to say nothing of R.N. and R.A.F. Emphasis is laid on the helpfulness of the Ceylon Government and local British and other officials. Tommy's only grouse seems to be the extortionate prices charged by shopkeepers.

Ten Days in the Hills is the narrative of a recent arrival in India on a walking tour between Simla and Kulu.

A Suggested Reorganization of Infantry proposes M.T. (3-ton lorries) for a whole battalion, and the attachment to each of a donkey troop for cross-country work. On motorable roads the mokes would be carried in trailers.

The Punjab Soldier at Home is a fascinating article, treating for the most part of the way in which the Punjabi sowar or sepoy, Muhammadan, Hindu or Sikh, is helping in the uplift of the countryside. The influence of his womenfolk, who see very little of the outside world, has so far been retrograde, but it is hoped that, with education, and the work of women's welfare centres, a great improvement will come to pass.

F.C.M.

THE INDIAN FORESTER.

(*November*, 1942.)—*Forestry after the War* assumes that the forest resources of India will be greatly depleted. The author pleads for their reconstruction, not so much from the material point of view, as from that of the æsthetic amenities. In a note, the Editor remarks that the forest resources of India are very far from approaching exhaustion. In spite of the enormous war demands (that for 1942 was the biggest yet) the felling in advance of working plans is not more than 1½ years' yield.

The effect of bombs on woodland is summarized. Old trees are blown down or broken, but young trees seem to bend to the blast, and the reviewer can corroborate the statement that 5-year old poles can be seen growing apparently unharmed on the lip of a crater. Other results are :—

Blast bombs—blow trees down and strip off bark, but do not damage the timber.

H.E. bombs, with thick walls, reduce them to splinters.

Parachute mine exploding in crown of a 30-year old larch wood—censored, but is described as very interesting.

(*December* 1942.)—Mr. Dent has been making experiments about the longevity of seeds, and has induced some to germinate after 41 years' confinement ; others nearly as old were induced to sprout, though many needed a filing of the seed covering. A table showing some world records names a variety of lotus as having germinated after 247 years, and a remarkable incident is recorded where a 147-year old seed of another kind germinated spontaneously after being wetted accidentally following damage by enemy bombs. Doubt is cast on the veracity of the sprouting of " mummy wheat." It should be mentioned that a previous number of the *Forester* mentioned 300-500 years as the dormant life of certain lotus seeds.

Ngaungwaing Depot in Lower Burma is described without a mention of its present temporary occupation by the enemy. It is a tidal basin and mud-banks are constantly changing, but it is essential to know the contours to a fraction of a foot, as large logs have to be stranded on the lowest patches and smaller ones higher up, in order to save subsequent labour in rolling, marking and refloating.

Editorial Notes record a duel between a tiger and a porcupine, resulting in the death on the spot of both combatants. The carcase of the porcupine was shorn of all its quills ; that of the tiger was covered with them. Save his eyes, quills were lodged all over his body, his four legs, in his lungs, heart and stomach. The Forest Research Institute, Dehra Dun, has been carrying out experiments regarding the effects of sapwood on the strength of *helves* of *babul* (*Acacia Arabica*) and mulberry. It was found that the presence of sapwood had no appreciable effect on strength.

Star grass, a native of Kenya, is one of the world's quickest growing plants. In 5½ weeks, a single plant, by means of runners sometimes 50 feet long, has covered 8,000 square feet of soil, growing to a height of 3 or 4 feet. This points out its value as a cover for soil liable to erosion. It is eaten with avidity by cattle, but, most disconcertingly, during acclimatization experiments in India, it was discovered to contain small quantities of prussic acid. The amount is however extremely small, and so far the result of trial on cattle has been favourable. Attempts are being made to reduce or breed out the very small amount. Mature star-grass hay holds no risk of poisoning.

(*January*, 1943.)—*A rare Investiture Ceremony* records the award of the Empire Gallantry medal to Mr. Edmund Joseph, a Ranger of the Indian Forest Service. With no previous navigational training, and only the rudiments of survey taught in the Ranger College in Dehra Dun, he successfully navigated the forest fleet of three small vessels from the Andamans to India, and so prevented them from falling into the hands of the Japanese. The method he employed was to sail north until the latitude of Polaris was equal to that of Vizagapatam, the port of destination in India, and then to sail along that parallel. His landfall was within 40 miles of that place, an amount almost within the permissible error due to the displacement of the Pole Star from the actual pole.

A use has been found for pine-needles, very common naturally in the forests of northern India, in the preparation of a resilient substance named pine wool, useful for mattresses, packing fragile articles such as fruit and eggs, and similar purposes.

F.C.M.

Invitation to tea

Shortage of fresh milk . . . the need for using tinned milk . . . the rationing of tea and sugar . . . all these war-time restrictions make it impossible for N.A.A.F.I. to serve tea "such as mother used to make" in its canteens.

In order to make the best use of the ingredients available, N.A.A.F.I. is launching a seven-point plan to ensure that the tea sold is of the highest possible standard.

An invitation is issued by N.A.A.F.I. to all Institute Committees to attend tea-testing meetings in their canteens. The Committee Members will then have an opportunity of sampling tea made according to the standard recipe, and will be able to submit their own criticisms and suggestions.

OTHER POINTS IN THE PLAN INCLUDE :

- Instructional talks to the staff.
- Regular tasting of the tea by all N.A.A.F.I. officials visiting Institutes.
- The issue of a special booklet to the staff on tea-making.
- Special courses for training staff before they are permitted to make tea in the canteens.

NAVY, ARMY & AIR FORCE INSTITUTES,

Ruxley Towers, Claygate, Esher, Surrey.