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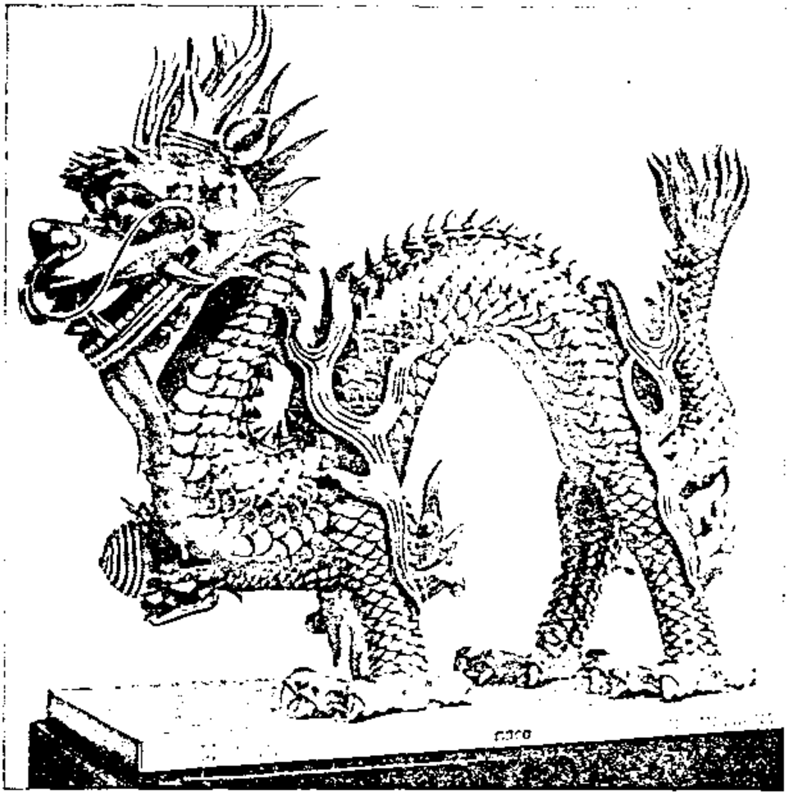

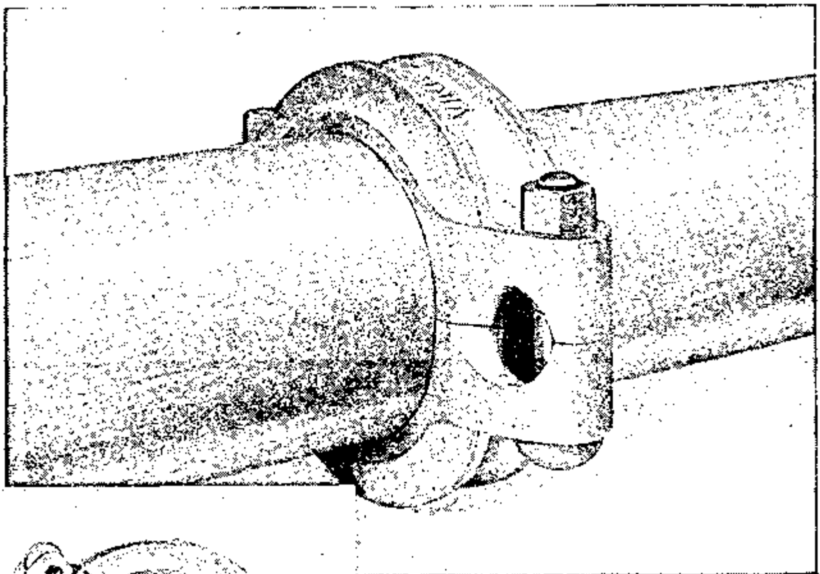

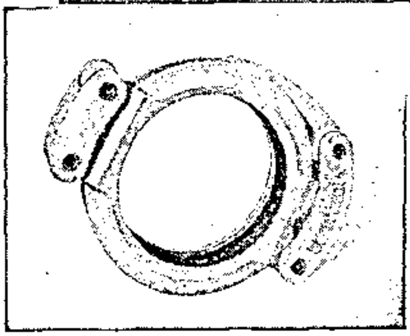

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MARCH, 1966

Gold Medal and Trench Gascoigne Prize Essay Competition 1964

The Trench Gascoigne First Prize Essay 1964 was awarded to Colonel A. E. Younger, DSO, OBE. His prize-winning essay was published in the November 1964 *RUSI Journal*, and it is republished here by permission of the Council of the Royal United Services Institution.

"The geographical situation of the free part of Europe which, as a consequence of World War II, has shrunk to such an extent and has now so little geographical depth, that even a unified Western Europe would not be capable of successfully defending itself without US assistance." Franz-Joseph Strauss.

This quotation from the ex-Defence Minister of the Federal Republic of Germany raises the vital strategic question of whether Europe can defend itself without United States help or not. General de Gaulle believes it can; and since he speaks with more authority than has been wielded by any Frenchman since Napoleon, his ideas carry great weight. It is clear that Herr Strauss holds the opposite view and the object of this study is to discuss the validity of his statement. It is first necessary to analyse the meanings of some of the expressions and words used in the quotation before it is possible to investigate the validity of the main thought behind it. What precisely is meant by "the free part of Europe" and by "a unified Western Europe"? Having decided on definitions of these, the main question can be considered of whether sufficient geographical depth exists to provide a successful defence.

Western Europe

In his statement Herr Strauss is probably referring to those NATO Powers indigenous to the continent of Europe, including perhaps Greece and Turkey. However, this leaves out Finland, Sweden, Austria, Switzerland, Spain, and Eire, all of which might be included in the free part of Europe. In order to apply the severest test to the main idea, the greatest possible number of countries should be included, as this will permit the maximum geographical depth. Certainly there is no difficulty in arguing that he might mean to include Sweden, Austria, Switzerland, and Eire. Although these countries have striven, and still strive, to be neutral in the event of war, they are undoubtedly in the free part of Europe both geographically and politically.

Finland is a different case. She stalwartly maintains her freedom, but it is difficult to imagine the Soviet Union ever permitting her to become a member of a unified Western Europe. In any case, as an outpost of freedom, Finland is so isolated that in the event of war the Soviets could virtually ignore her or, at worst, contain her with minor forces. On balance it seems more sensible to omit her from Herr Stauss's unified Western Europe.

Whilst there is no doubt that the vast majority of governments and citizens of Western Europe would welcome Finland into their community, Spain, the farthest from Russia, might find her entry vetoed because of her Fascist and World War II history. However, sympathy for and friendship towards Spain increases steadily. Strategically, Spain would increase the geographical depth of a unified Western Europe. For the purpose of this paper it will be assumed that she is included in Herr Strauss's concept.

There is a possibility that Yugoslavia might join a unified free Europe, particularly in the long term, but this is too unlikely to be considered in this analysis. In fact the opposite will be assumed, namely that Yugoslavia will actively side with the Communist Powers.

Therefore, to apply the severest test to the statement it will be assumed that all of Europe outside the Iron Curtain, plus Turkey but excluding Finland and Yugoslavia, are included in the term "free part of Europe".

Physical Geography

The generation that has both fought World War II and benefited from the excellent tourist facilities of the mid-20th century is all too familiar with the physical geography of Europe. But having driven their jeeps, trucks, or private cars great distances across the Continent, many may have developed the thought that no barriers to large-scale military movement exist. Even the Alps shrink in significance under the shadow of the internal combustion engine that conquers the high passes a hundred times an hour each summer's day.

But geographical depth is a relative term; it is increased by barriers to movement and decreased where none exist. The road network in Western Europe is very good and improves yearly, but barriers can be developed and these must be taken into account before any comprehensive decision can be made whether sufficient depth exists for defence.

The North European Plain. The dominating geographical feature of Western Europe is the North European plain, stretching from the Urals to the Atlantic. Its importance is enhanced by the fact that the industrial heartland of the subcontinent lies within it and the only major industries to lie outside it are those of Italy and the British Isles. A Soviet advance across the plain from their bridgehead in Eastern Germany to the Atlantic would cut Western Europe into halves and deal a crippling blow. Since the road network it carries is excellent, it is important to consider what obstacles to movement exist in the plain.

The main potential obstacles are the river lines of the Weser, Rhine/Meuse, Seine, and Loire with their dependent canal systems and tributaries. The countless bridges that span these waterways could be destroyed by a properly organized authority. Roughly along the Franco-German and Franco-Belgian frontiers, the curve of the Jura, Vosges, and Ardennes mountains, reinforced by parallel ridges running through Lorraine and Champagne, provides the only other extensive obstacle. However it is not continuous. It is split by the Belfort and Strasbourg gaps and there still remains the plain of Flanders between the Ardennes and the sea. The effect of this high ground is to constrict the great plain and give enhanced strategical importance to the Flanders part of it.

Other obstacles or potential obstacles of limited importance exist in the plain, rather like islands in a sea. The main ones are industrial complexes, of which the Ruhr area is much the largest, but the Paris and Brussels areas are also significant. As the big towns steadily expand, these man-made jungles will become more important features. Secondly, the low-lying areas of the Netherlands and along the rivers of North Germany, including the Steinhuder Meer, obstruct movement at certain times of the year. Lastly, some hills exist, particularly near the Weser in Germany and in northern France; unfortunately they are not sufficiently extensive to have strategical significance, although they could be of great importance tactically.

Seen from Moscow, the North European plain must appear an inviting avenue of approach from Poland and East Germany to the Channel and Bay of Biscay. Flanked by mountains to the south and sea to the north, it offers to support a maximum concentration of force. If the flood of invasion from the east could reach the constriction of the Flanders plain, it would already have neutralized the industrial might of Germany and the Low Countries. Beyond that, the heart of France lies open and few obstacles exist until the Atlantic coast and the foothills of the Pyrenees are reached.

Remainder of Europe. Western Europe may be considered rather as an animal, where the North European plain is represented by the body and the remaining countries by limbs. It would be a happy arrangement for the defence of Europe if centres of power existed in the hands and feet at the extreme tip of each limb. Then an aggressor, having overrun the body, would have to battle his way up the length of each arm or leg to complete his campaign. However, if the concentration of power is all at the shoulders or hips, there is little strategic value in the limbs.

For example, it is unfortunate that Italy's main contribution to European civilization comes from the fertile Po valley. This fact means there is small value in the complex hill systems to the south, since they cover no critical heartland.

Considering the rest of Europe, moving counter-clockwise from the north, rather the same circumstances occur in the Scandinavian limb. The rich, populated areas are the Danish Islands and southern Sweden, nearest to the body. The long fjord-indented and mountainous peninsula to the north has no protective importance against an attack from the south. Since it would be a great strategic gain for the Soviets to control the sea exits from the Baltic, they are most likely to attack from the south, and not attempt a major effort from the Arctic.

Iceland only has importance if America requires it as a base. This is not to say that Iceland should withdraw from NATO into isolation. If Europe were conquered by Russia, this bleak island would be equally important as a defensive or offensive outpost against America and might well be the scene of fierce conflict, but *after* the main battle for Europe had been finished.

The British Isles are protected by the seas that surround them to an extent that decreases with each advance in technology. The ranges of modern weapons, the speed and capacity of air movement, to say nothing of helicopters, submarines, and air cushion vehicles, have reduced the salt water barrier to a very small hurdle compared with the insurmountable one that faced Napoleon and Hitler. But this water remains as a major fact in the geography of Western Europe. In the early stages of a war, the Channel would be a disadvantage to free Europe if the Soviets had air superiority, since the movement of reserves across it might be jeopardized.

The Pyrenees protect the Iberian Peninsula, whose many mountains provide more geographical depth than any other part of Europe. However, the significance of the Peninsula in terms of power is not great.

Italy has already been mentioned. It is again unfortunate that the Alpine barrier of Austria and Switzerland, that offers to guard her from the north, is largely outflanked by Yugoslavia.

The comparatively arid islands of the Mediterranean, both large and small, have no value as depth since they protect no centre of power.

Finally, Greece and Turkey complete the picture. Potentially their mountainous nature should provide good geographical depth, but their locations, with Communist Powers on their immediate northern borders, nullify this. All the same, their presence within a European alliance diverts some of the strength of the enemy, and therefore decreases his chances of victory.

To generalize the physical geography of Western Europe, the main power of its civilization is found in the North European plain. Attached are a number of areas of differing shapes, sizes, and importance, each of which would be capable of independent military action for varying, limited periods, and whose presence dilutes the enemy strength in the plain. Military co-ordination between them would be most difficult in the face of an enemy controlling the whole plain.

However, if there lies within this sub-continent sufficient depth for defence, then the original statement is false; if not, it is valid. The next step therefore must be to define geographical depth and measure the requirement for it against the land mass available in Western Europe.

Geographical Depth

"Geographical depth" as used in the quotation is a strategical term and, when considering the strategic implications of defence, depth has importance in military, economic, political, and psychological fields. These will be considered in turn, and an attempt will be made to reach a decision in each case whether sufficient depth would exist for the successful defence of a united Europe.

The military aspect strikes the mind first, but the relative value of depth in the context varies, with the type of war being considered; an area of country that would provide sufficient depth in the event of attack with one family of weapons and means of movement, would be insufficient against another family with increased ranges and speeds. An historical example is therefore only of value if it provides a base from which a projection into the future can be made. However, an example also serves to illustrate the meaning of the four different aspects of depth enumerated in the previous paragraph.

World War II. Unfortunately for this study, but fortunately for Europe, there is no recent example of an attack from Russia to the Atlantic, so no direct comparison can be made. The closest historical point of departure is World War II and, even then, only the initial German attack on Russia bears any strategic resemblance to a possible Soviet attack on Western Europe at the present time. No two campaigns are ever the same and the differences between the Russo-German conflict in 1941 and a possible Soviet attack now are far too numerous, and too obvious, to list. It is more profitable to consider the strategic similarities and from them try to learn from the past.

In general terms the German advance, starting from East Prussia, the middle of a divided Poland, and Rumania, and continuing to the gates of

Moscow and Stalingrad, achieved a penetration of the same order of magnitude that a Soviet advance from the Iron Curtain would need to reach the Pyrenees and Bay of Biscay. The Germans found it necessary to dilute their main effort by a thrust to the Caucasus in the south, rather as the Soviets might have to dilute theirs to neutralize Italy. Again, the Germans employed forces to advance from Finland and tie down opposing troops in the far north. In a similar way the Soviets would have to put some effort into this flank, particularly as Sweden, which provides the nearest bases for counter-attacks on Leningrad and Moscow, has been included in the united Western Europe. Nothing like the modern Soviet's problems in Greece and Turkey existed for the Germans, but these comparisons should not be carried too far. Nor is there any need to do so. It is sufficient that the main effort in each case has supplementary secondary efforts on each flank.

The nature of the attacking alliances is broadly similar, since both have supporting forces from satellite countries and the ultimate loyalty of these forces may be questioned in each case. But the great preponderance of strength lies with the main aggressors. On the other hand, it is questionable if the defending alliance in the case of Western Europe is likely to achieve the monolithic cohesion of Stalin's Russia in 1941; a comparison operating in favour of the possible Soviet attack on the West.

Improvements in technology allow a modern army to move farther and faster than the Germans did and deal paralyzing blows of a type unknown in 1941. This comparison again operates against the Germans but, above all, they had to contend with more than 4,000 miles of depth behind the Volga.

Such evidence as is available indicates that the decision to attack was strictly Hitler's own. All his conquests until then had been accomplished in a matter of days, and presumably he reasoned that a matter of weeks would be sufficient for his armies, then highly experienced in "blitz-krieg" techniques, to bring Russia to her knees. He failed, but there was one moment when it is conceivable that success was within his grasp.

In the autumn of 1941 Stalin decided that the Japanese would not attack him in the Far East. Some say that this information was deliberately leaked by Tokyo, but whether it was or not, Stalin was sufficiently sure of himself to denude his defences along the Amur River and to remove a completely fresh, well trained army to the Moscow front. If this army had been tied down by a Japanese threat, it is likely that the Germans could have reached Moscow and consolidated along the line of the Volga.

Stalin was truly saved by the geographical depth available to him. Even without an airforce capable of stopping the Luftwaffe, an army was brought from far beyond their bomb range and committed to the critical sector at the critical time. But supposing the Japanese had made a demonstration and Stalin's army had been forced to remain in eastern Siberia, and that therefore the Germans had taken Moscow and his government had collapsed. His geographical depth would still have been the same, but he would have lost. It might therefore be said that geographical depth was not vital. This is to misunderstand the full meaning of the term. As has been said above, geographical depth has several aspects of which only one is military. There is also a political one. If adequate governmental powers exist, new forces can be raised and new obstacles placed in front of invaders, provided also that the economy of the country is sufficiently intact and that there is still a will to fight, or, in other words, that economic and psychological 'depth' is present.

This short look at the German campaign in Russia in 1941, apart from illustrating the various aspects of depth, provides little encouragement for the free world today. Before winter set in, Hitler had overrun an area greater in size than the European plain from the Iron Curtain to the Atlantic. Circumstances were different, and clearly if advances of this order of magnitude were possible then, they should be even more possible now.

The Need for Depth. Since the military requirement for depth is to permit reserves to be moved to a critical area in time to prevent defeat, at the start of a war sufficient time must be available for most of these reserves to be mobilized, as well as moved. If the war is prolonged, they will have to be "called-up" and trained also. In this connection, time and space are interrelated and the main question is whether Europe has sufficient space to drag out the length of a war so that reserves can become effective.

Speculation on the length of a future war is notoriously unreliable. Past experience indicates that governments invariably underestimate it, but this provides little guidance. However, it is not the primary object of this study to decide on the length of a future war in Europe; to do so would require a separate analysis of highly classified data. The best that can be done is to make some broad generalizations, but, knowing that the weighing of the various factors involved is anyone's guess, it is as important not to be too optimistic as it is to avoid excessive pessimism.

Since the type of war has a bearing on its probable length, the time and space equation must be solved for each possible alternative type. This will be done under the major classifications of nuclear and conventional war, and finally the alternative of a conventional war escalating into the use of tactical nuclear weapons will be considered.

Nuclear War. There is small hope that the centres of civilization in Western Europe would survive an initial strike by nuclear delivery systems if the Soviets chose to start a war in that way. This is particularly true if America were not engaged in the contest. Certainly it is to be hoped that the combined power of French and British nuclear retaliation would inflict a similar, or at any rate an unacceptable, degree of devastation on the Soviet Union, but this would not alter the fact of destruction in the West.

The time and space equation for measuring depth has little meaning when the whole of Europe lies within the range of Soviet missiles, and when the quantity and accuracy of these are sufficient to paralyze modern life in the area. Even if the West still had the will to engage in "broken-backed" warfare, the degree of destruction caused by a nuclear exchange would amount to a major defeat.

There is little enough sense in engaging in a nuclear exchange even if the great power and space of the North American continent is added to that of Europe, but at least there is the hope that Russia could be beaten to a halt before Europe were paralyzed. Without America there can be no such hope.

In the context of an all-out nuclear war, therefore, the sheer weight of Soviet nuclear power makes Herr Strauss's statement valid.

Conventional War. It is under conditions where only the so-called conventional arms are used that some estimate of the length of the war must be made. This can be done by assuming the relative strengths of the contestants and then, based on experience, estimating how long it would take to reach a decision.

The effective ratio of conventional forces between East and West can never be predicted exactly, since the ability of either side to concentrate fully must depend on the circumstances surrounding the period of tension before hostilities commence. The Soviets are credited with 150–160 divisions and NATO with 24 capable of being brought to bear on the European plain, not including uncommitted French forces. It is too much to expect that the former could concentrate so many divisions without alarming the West to the point of mobilization. On the other hand the problems of concentration should not be exaggerated. The German Army succeeded in collecting two Panzer armies for their Ardennes attack in the winter of 1944, and in this effort they achieved almost a complete surprise at a time when not only was Allied air supremacy at a maximum, but also natural cover was at a minimum. An aid to large Soviet concentrations is that, if carried out steadily and slowly, it is difficult for free countries to pick a point at which the danger is sufficiently urgent for them to order mobilization. In any case there is a natural reluctance to give such an order in view of the wide publicity it attracts, and the fear that it would make war more certain by increasing international tension.

Probably something of the order of 100 Soviet divisions could be brought to bear from East Germany, Poland, and Western Russia so as to be of significance in a conventional assault on the West. Behind these some satellite formations could certainly be alerted in sufficient time to guard flanks and clean up pockets of resistance.

Against this NATO offers a shield of 24 divisions, but six of these are American. Western European strength would be puny without the American contribution, although there would be an augmentation from Sweden, Spain, and the other countries which could join a united Europe. However, it is unlikely that these additional countries would contribute anything very effective to protect the European plain; they would be tied to protecting their own countries, except, possibly, for Spain. The only sizeable increase could come from France. She could replace two and later three, of the six American formations and could throw in her airborne division.

Assuming Soviet divisions to be at two-thirds the strength of those of Western Europe, the former would still be able to boast a three to one superiority of conventional forces, even assuming secondary efforts on the northern and southern flanks. Obviously the West would work to reduce this discrepancy, but since no weight has been given to Soviet satellite strength, the basic ratio is not likely to change much.

Bearing in mind the geography of the North European plain and the obstacles within it, it must also be remembered that refugees in a future war will choke the roads initially, and that unfortunately these impede the defence more than a ruthless aggressor. So, with the quantity and quality of mechanization available to the Soviets, together with their airborne capability, it seems unlikely that a mixed European force, lacking US air or ground power, could hold out for long. It took Hitler less than a month to sweep through the Low Countries and France; it is hardly likely that modern armies, even starting from the more distant Iron Curtain, would take longer, assuming similar success in destroying bridges as was achieved by Franco-British troops in 1940.

The question then arises whether sufficient reserves of trained manpower could be mobilized to be rushed into the battle and have a decisive effect. Only Spain and the United Kingdom could do anything, helped by *Defence Operationelle du Territorie* (DOT) forces from parts of France not already overrun. Spain, having deployed to defend the passes in the Pyrenees, might contribute a brigade or two. In these circumstances the task placed on the shoulders of the British stategic reserve and territorial forces and the French DOT forces would be far beyond their capabilities.

The plain truth is that with modern conventional weapons and means of transportation there is insufficient depth to prevent Soviet armies from overrunning the heartland of Western Europe. This is the decisive fact. The remaining countries on the periphery would subsequently be comparatively isolated and in grave danger of being reduced one by one, but even if they survived it would be a long and infinitely difficult task for them to retake the heartland without American help.

Escalation. There remains the possibility that there might be a different result if the West countered a conventional Soviet attack with tactical nuclear weapons. Such escalation is more than probable, since Western Europe is unlikely to be able to hold an attack by using only conventional weapons. Under these circumstances it might be hoped that the use of tactical nuclear weapons would cause the Soviets to stop and therefore give the West some valuable time. This seems highly unlikely as the Soviets will have foreseen the eventuality, but in any case doubt about possible American reactions would cause them to halt and consider some political solution. Therefore the American deterrent, and not European power, should take credit for stopping the war.

If, on the other hand, the Soviets did not pause but accepted the escalation, there is little hope that transition to the full nuclear exchange could be long delayed. In this event the factors listed above under nuclear war apply.

To summarize, if only conventional weapons are used, the war would not be long enough to permit decisive forces to be mobilized to prevent the Soviets from overruning the heart of Western Europe's civilization. Any different result is most improbable if tactical nuclear weapons are used. Herr Strauss's statement is therefore valid in the military aspect of geographical depth.

Non-Military Aspects

These have been described earlier as the fields of economics, politics, and psychological warfare in which some 'depth' is also needed for the successful prosecution of modern war. Regardless of her military strength, it must be considered whether the American contribution in these fields is vital to Europe.

Western Europe, if united to the maximum extent described above, would exceed the population of the USSR and all its European satellites by about 5 per cent and, what is more potentially significant, would have a total gross national product 15 per cent greater. Therefore, the great strength of America, which incidentally in terms of gross national product comfortably exceeds that of the USSR and all Europe together, should not strictly be necessary.

Politically, the 19 independent governments of Western Europe are groping slowly towards a union. Sir Winston Churchill observed in 1946 that

Europe had been reduced to "a vast quivering mass of tormented, hungry, careworn, and bewildered human beings. . . . Yet all the while there is a remedy. . . . We must build a kind of United States of Europe." Now, in 1964, the peoples are not in such a desperate state, but there is clearly a very long way to go before a firm political union becomes a reality.

These political and economic aspects are closely bound together and cannot be separated. If Western Europe were politically fully united, a tremendous volume of economic energy would be released within her boundaries by the removal of duplication of effort. Pure administrators, such as customs officials, would be available for productive employment, and the true wealth of the whole community would increase. The adoption of one currency and one set of weights and measures alone would eliminate a great amount of non-productive work, all of which detracts from the wealth of the people today. Until the day when there is such a union, it must be concluded that the political and economic power of America is necessary to balance that of Soviet Russia; but for the purpose of this study it must be assumed that a true union is possible.

There remains the psychological or morale aspect. Great leaders have made different appraisals of the part this plays in war, but all are agreed that its importance is second to none. If the people of Western Europe do not really believe they could, without American help, emerge victorious after a Soviet attack, they are likely to be defeated. Similarly, and equally important, would the Soviet leaders and troops feel more likely to succeed?

The effect of an American withdrawal on the Soviets cannot be doubted. They might foresee certain difficulties in conquering a united Western Europe, but these are small compared with those that would arise if the power of America were launched against them, so their morale should rise.

Against this, the morale of Europeans could only fall. It is a satisfying thought for those who have to live near the front line that great power exists behind them to deter an aggressor. They know they can be overrun at any time; they always have known this. Today they feel comparatively safe, protected by dispersed installations in the far plains of Nebraska and Wyoming. It cannot be supposed they would feel the same if this deterrent power were removed. However Churchillian the leader of a united Europe could be, it is likely that a sense of impending doom would sap the Western Europe spirit.

To summarize these non-military aspects, if a united Western Europe could reorganize itself drastically as a single State, then politically and economically it could dispense with American help. The possible date of completion of such a task is far in the future, and until it arrives it would be foolhardy to attempt to stand alone without America. Even if this union came into existence, the psychological advantage of having America as an ally is a major factor.

Europe's Need

It is not just the needs of France, but those of Western Europe as a whole, that are under consideration. An increase in the power of France, particularly if she is the centre of a united Europe, does represent an increase in the power of Europe. Even if the increase in French power is made at the expense of a decrease in the power of other free States, it could still be a net improvement for Europe if French statesmanship and leadership were demonstrably the best in Europe. President de Gaulle presumably believes it is, and he may be right, but it is doubtful whether the rest of Europe will accept this. However, although it represents an improvement over none, French leadership over part of free Europe cannot in the foreseeable future replace the effectiveness of American leadership, backed by American power.

If Western Europe can become truly united, a process that will take a great deal of time and effort, it is possible that she could face the Soviet Union and her satellites alone in the economic and political fields, but she will have sufficient depth neither militarily nor psychologically.

There seems to be a serious danger in de Gaulle's policy that he will so antagonize the Americans that the latter will leave Europe before it even becomes united. Such a possibility would be worse for Western Europe than abandoning the pilot before entering port; it would be abandoning the fuel for the engines as well. So far American leadership has shown a greater sense of responsibility than even to hint at such a line of action.

Conclusion

Herr Strauss's statement is shown to be valid even allowing the widest interpretation of the term Western Europe. The preponderance of Soviet strength is such that, even if unified, Western Europe has too little geographical depth in which to defend herself successfully against either nuclear or conventional attacks. Rather than contemplate the perils of a defence without US assistance, it would seem more profitable to join Jean Monnet in recognizing, for both Americans and Europeans, "that neither one nor the other is defending a particular country, but that the ensemble is defending a common civilization".

SILVER CENTERPIECE

The Broken Link

By T.D.V.

AT Chatham on 18 November 1965 the Chief Royal Engineer, General Sir Frank Simpson, GBE, KCB, DSO, presided at a Corps Guest Night when, on behalf of the surviving Sappers, ex-Cadets of The Royal Military College, Canada, Major-General G. S. Hatton, CB, DSO, OBE, presented a silver centre-piece to the Corps.

Those present included senior representatives of the Royal Navy, Royal Air Force and Civil Service, the QMG and MGO, the Engineer-in-Chief and most senior serving Sapper officers, as well as senior officers of other arms. Major-General Pat Bogart, President of the Royal Military Club of Canada (UK Branch) and six Sapper ex-Cadets were also present.

Following some brief introductory remarks, Major-General Hatton continued as follows:—

"My speeches in this Mess follow a similar pattern. When I was a young officer and had the inclination to say quite a lot, I did not have the opportunity, but now that I am no longer young, and have the opportunity, I have some disinclination to speak. The reason for my disinclination is that what I would like to say, and what my fellow ex-Cadets here would like to hear me say is that: 'Every year henceforth one or more gentlemen from the RMC Canada will be commissioned into the Corps.' Unfortunately, this cannot happen.

All our efforts with the Chiefs of Staff and Adjutant-Generals in this country and more expecially in Canada (and they have been considerable)[1] to re-establish the link between the RMC Canada and the British Army have failed. The reasons are economic, political and military. They are as understandable to us as they are regrettable.

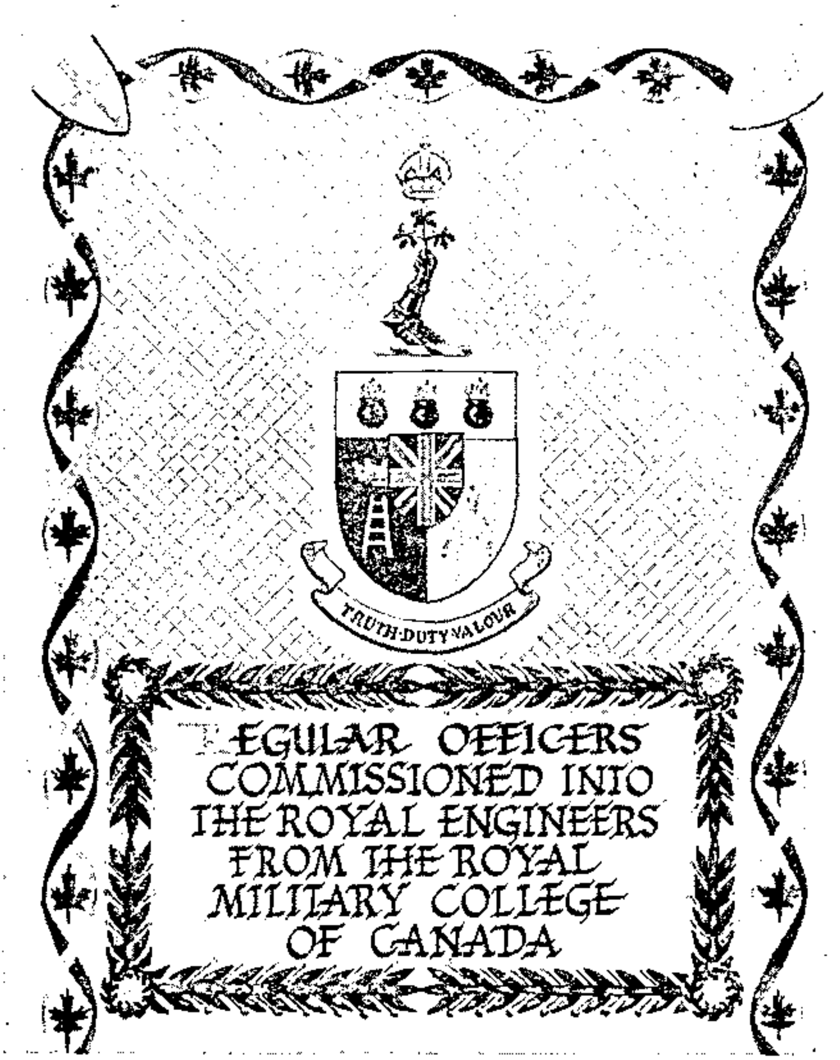
It, therefore, seemed desirable that this link, and particularly that between the College and the Corps, should be commemorated. Between 1884 and 1942 no less than 125 ex-Cadets of the RMC Canada were commissioned into the Corps as regular officers.

Despite their early difficulties in learning the language, many of them rose to high rank and command, including ten generals, amongst them General Sir George Kirkpatrick and Lieut-General Sir Edward Grasett, for whom I am deputizing tonight in his unavoidable absence. Others distinguished themselves as engineers, notably: Sir Percy Girouard, Sir Godfrey Rhodes, and Sir Frederick Carson. We also achieved a Commandant of the Royal School of Military Engineering—your late Commandant, Brigadier Jim Carr, who is with us tonight, and to whose initiative and energy we are indebted for the procurement of this centre-piece.

[1] Details of these efforts which were not included in the address, are as follows:

At the end of the Second World War, the Canadian Government decided they must maintain a much larger Regular service than had been the case before 1939. Thus all the products of an expanded Cadet training scheme were required for the Canadian Army, Navy, and Air Force. There was no longer any authority for applicants from Kingston to join the British Army and thus it came about that by 1945 the RE had already accepted the last of a long line. Since 1945 many attempts have been made to regain the scheme but without success.

The last such attempt was made in 1963/4 when negotiations with Lieut-General G. Walsh (late RCE) the CGS Canadian Army, Major-General W. Anderson the Adjutant-General, Canadian Army, and the Adjutant-General, the War Office, failed to arrive at an answer which would be satisfactory to all interested parties.


TRUTH·DUTY·VALOUR
REGULAR OFFICERS
COMMISSIONED INTO
THE ROYAL ENGINEERS
FROM THE ROYAL
MILITARY COLLEGE
OF CANADA

1880 MAJ-GENERAL A.B. PERRY, CMG
1881 CAPTAIN H.R. MACKAY, DSO
1883 COLONEL A.H. VAN STRAUBENZEE
1883 CAPTAIN W.M. ROBINSON
1883 COLONEL J.I. LANG-HYDE, CMG, OBE
1884 COLONEL H.C. CAREY, CMG
1885 MAJ-GENERAL D.M. RIDOUT, KBE, CB, CMG
1885 COLONEL W.J. McELHINNEY
1885 COLONEL G.M. DUFF, CIE
1885 CAPTAIN W.G. STAIRS
1885 COLONEL REV CANON T.H. A F. CASGRAIN
1885 BRIG-GENERAL H.C. NANTON, CB, CIE
1885 BRIG-GENERAL A.C. JOLY de LOTBINIERE, CB, CSI, CIE
1885 LT-COLONEL E.G. VON HUGEL
1885 LT-COLONEL T.C. SKINNER
1885 LIEUT A.T. BREMNER
1885 MAJOR W.F. TILLEY
1885 CAPTAIN H. SLOGGETT
1886 BRIG-GENERAL G.S. CARTWRIGHT, CB, CMG
1885 GENERAL SIR G.M. KIRKPATRICK, KCB, KCSI
1886 BRIG-GENERAL SIR P.G. TWINING, KCMG, CB, MVO
1886 MAJOR J.N.C. KENNEDY
1887 2 LIEUT A.L.F. DAVIS
1888 BRIG-GENERAL H.G. JOLY de LOTBINIERE, DSO
1888 MAJ-GENERAL SIR E.P.C. GIROUARD, KCMG, DSO
1888 MAJOR A.A. ADAMS
1888 BRIG-GENERAL W.B. LESLIE, CB, CMG
1888 CAPTAIN C.B. FARWELL
1888 BRIG-GENERAL A.E. PANET, CB, CMG, DSO
1888 BRIG-GENERAL A.G. BREMNER, CMG
1889 COLONEL H.S. ROGERS, CMG, DSO
1890 LT-COLONEL H.B.D. CAMPBELL
1891 BRIG-GENERAL D.S. MacINNES, CMG, DSO
1892 LT-COLONEL W.C. DUMBLE, CBE
1894 COLONEL B.H.O. ARMSTRONG, CB, CMG
1894 MAJOR G.F.E. OSBORNE, DSO
1895 BRIG-GENERAL G.E. FRITH, CB, CMG, DSO
1896 LT-COLONEL A.S. EVANS
1897 LT-COLONEL A.L.C. de B. DOUCET
1898 LT-COLONEL G.W. DENISON, DSO
1899 CAPTAIN G.D. CARR-HARRIS
1899 COLONEL H.L. BINGAY, DSO
1900 CAPTAIN E.C. BAKER
1900 LT-COLONEL F.M.W. ARCHBOLD
1900 MAJOR G.D. JOHNSON, OBE
1901 MAJOR T.C. KEEFER
1902 COLONEL D.K. EDGAR, DSO
1903 BRIGADIER W.G. TYRRELL, DSO
1904 BRIGADIER E.F. DAWSON, CIE, MC
1905 MAJ-GENERAL E.J.C. SCHMIDLIN, MC
1906 LT-COLONEL J.D. GEMMILL, MC
1907 BRIG-GENERAL SIR G.D. RHODES, KT, CB, CBE, DSO
1907 MAJOR G.L. RIDOUT
1908 BRIGADIER SIR C.F. CARSON, CBE, MC
1909 LT-GENERAL SIR A.E. GRASETT, KBE, CB, DSO, MC
1910 BRIGADIER SIR E.O. WHEELER, KT, MC
1911 BRIGADIER H.G. JOLY de LOTBINIERE, MC
1912 MAJOR E.P.C. SWEENY, OBE
1913 MAJOR E.H. de L. GREENWOOD, CD
1914 MAJOR C.V. STRONG, MC
1914 MAJOR A.C. BROOKS
1914 BRIGADIER H.G.P. GREENWOOD, CBE, MC
1914 CAPTAIN F.D. ASHCROFT
1914 COLONEL C.B.R. MACDONALD
1914 COLONEL W.M. MILLAR, CBE, MC
1915 MAJOR G.S. RIDOUT, MC
1915 MAJOR F.J.F. GIBSON
1915 BRIGADIER H.T. GENET, MC
1915 BRIGADIER H. de L. PANET, CBE
1915 CAPTAIN F.G. AVERY, MC
1915 CAPTAIN Y.G. FAWCETT, MC
1915 LIEUT G.L. KEZAR, MC
1915 CAPTAIN G.D. McTAGGART, MC
1915 LIEUT D.L. SAVAGE
1916 CAPTAIN R.Q. GODSON
1916 COLONEL R.A.H. GALBRAITH, OBE
1916 BRIGADIER W.D. ROBERTSON, DSO
1916 LIEUT J.W. INGS
1916 MAJOR R.L. CHALLONER, MC
1916 MAJOR G.G.M. CARR-HARRIS
1917 LIEUT N.D. MACKAY
1917 LT-COMMANDER D.H. MACKAY
1917 LIEUT A.W. SEELS
1917 LT-COLONEL R.D. ROSS
1917 LIEUT C.S. GEORGE
1917 MAJ-GENERAL G.S. HATTON, CB, DSO, OBE
1920 LT-COLONEL G.D.S. ADAMI, OBE
1921 LIEUT H.R. SCULLARD
1922 LT-COLONEL C.B. BOULTON, OBE
1922 LT-COLONEL R.E. MAY
1923 CAPTAIN O.E.L. JAMES
1924 COLONEL J.E.T. NELSON, DSO
1926 LT-COLONEL N.A. DAVIS, OBE
1926 LT-COLONEL J.B. SUTHERLAND, DSO, OBE
1927 BRIGADIER B.M. ARCHIBALD, CBE, DSO
1927 COLONEL H.C. SMITH, OBE
1930 LT-COLONEL J.J.D. GROVES, MC
1931 BRIGADIER H.R. de B. GREENWOOD
1931 LT-COLONEL R.T.L. ROGERS
1932 BRIGADIER J.G. CARR, CBE
1933 LT-COLONEL P.E. HOLMES
1934 LT-COLONEL H.M. MILLAR
1934 CAPTAIN H.C. de BLOIS
1935 MAJOR F.S. CARSON, MC
1935 MAJOR R.B. WOTHERSPOON
1936 LIEUT A.F. GALLOWAY
1936 BRIGADIER S.H. STEVENS, MBE
1937 COLONEL H.F.G. BOSWELL, OBE
1937 LIEUT J.H.K. CALVERT
1937 LIEUT D.E. BRADFORD
1937 MAJOR R.D. McLEOD, MC
1937 COLONEL J.G. OSLER
1938 LT-COLONEL R.E. THOMPSTONE, DSO
1939 LT-COLONEL T.T. NATION
1939 MAJOR S.D.I. SWEENY, MC
1939 MAJOR D.H. GIBSON
1939 CAPTAIN J.M. OLDHAM
1939 2 LIEUT J.D. HAMILTON
1939 MAJOR R.H. BOSWELL
1940 LT-COLONEL D.F.W. AITKENS, MC
1941 LT-COLONEL W.D.C. HOLMES, MC
1942 MAJOR T.J. CARSON

All did not achieve such rank and titles. Some were killed in action, some were severely wounded and retired early, while for others the ball did not bounce the right way. So they fill the whole gambit of ranks in the Corps from 2nd Lieutenant upwards.

As one grows older one realises the illusion of rank and titles. For this reason, it is wise for us occasionally to read or re-read Kipling, and observe the real worth of such humble characters as Gunga Din.

As you enter the Centre Court at Wimbledon, you are greeted with this advice, from Kipling's '*If*':—

'Meet with Triumph and Disaster and treat these two impostors just the same.'

An excellent admonition that has the widest connotation—far beyond the realm of sport.

No doubt there was an 'If' attached to one and all of the 125 which, for better or worse, accounted for their relative success, which is of no great significance; but as a body of men, and this is what matters, they have been and are, a credit to the College from which they came and the Corps in which they served. Unfortunately, their like will not be seen again.

Mr President, it is my privilege and pleasure, on behalf of the surviving Sapper ex-Cadets of the RMC Canada to present to the Corps this silver centre-piece, representing the 'RMC Arm' and inscribed as follows:—

Presented, in gratitude, to
THE CORPS OF ROYAL ENGINEERS
by the surviving ex-Cadets from the
ROYAL MILITARY COLLEGE OF KINGSTON CANADA
to commemorate the regular service of the
125 CANADIANS COMMISSIONED INTO THE CORPS
between the years 1880 and 1942.

With it is a scroll with the names of all 125."

General Sir Frank Simpson suitably acknowledged the presentation and the loss the Corps had sustained by this unavoidable break with the RMC, Canada.[1]

[1] Two young maple trees have also been planted, one on either side of the War Memorial at Chatham.

Slag as an Engineering Material

By Major N. D. CLIFFORD, BSc, RE

"SLAG—(1) *The dross or waste matter remaining after a metal has been extracted from its ore.*

(2) *A vitreous substance, composed of earthy or refuse matter, which is separated from metals in the process of refining.*"

The Oxford English Dictionary

INTRODUCTION

What is Slag? B.S. 812 of 1960—"Methods for sampling and testing mineral aggregates, sands and fillers" recognizes slag as a source of aggregate and defines it as "fused or partly-fused compounds of silica in combination with lime or other bases, resulting from the reduction of metallic ores". Slag is composed mainly of a number of alumino-silicates of calcium and magnesium, and is thus akin to some basic igneous rocks—the nearest thing to it in nature is volcanic lava. Since slag is initially produced in the molten state, its density and strength, and thus its suitability as an engineering material, depend very much on the way in which the molten slag is cooled and solidified.

Historical Background. The Romans were probably the first to appreciate the value of a rapidly cooled mineral aggregate. The Pantheon, built in the second century, incorporated lightweight concrete made with pumice aggregate and the ruins of Pompeii show several instances of this and the use of dense lava aggregate, while many of the Roman roads in this country are made with slag produced in the early ironworks. Slag is a product of heavy industry, and it is only comparatively recently that its properties have come to be fully appreciated by the civil engineer. Slag was used in the 1930s both for concrete, particularly lightweight concrete, and for road building, the first British Standard on the subject being published in 1939, but it was not until the post-war boom in road construction and building brought about a greatly increased demand for aggregate that the slag industry as such was really developed.

Scope of the Article. This article is intended as an introduction to the use of slag in the civil engineering and allied industries, and is by no means an exhaustive study of the subject. After some introductory remarks, the article concentrates on the production and use of blast-furnace slag. The body of the article is in three main parts:

Part I—An introduction to slag.

Part II—Blast-furnance slag.

Part III—Some uses of blast-furnace slag.

Finally, some possible application of the use of slag in military engineering are considered.

Reference Works. The manufacture of slag and its use as an engineering material are covered in various British Standards: these, and other reference works, are mentioned in the text and a Bibliography appears at the end of the Article (Annex "A").

Part I—An Introduction to Slag

General Background

The Extraction of Metals. The non-metallic by-products resulting from the extraction of a metal from its ore, or the further refining of a metal, are termed "slag", and, as the dictionary definition at the head of this article implies, slag was, until comparatively recently, considered to be a waste product. The proportion of slag to metal produced in the extraction process is usually fairly high, and in the case of iron ore the volumetric ratio of slag to pigiron is about 7 : 1, although this ratio depends to some extent on the richness of the ore and the efficiency of the process.

Slag—From Waste to By-product. In the early part of the industrial era, slag was regarded as waste and was dumped to form the slag heaps which are a unfortunate feature of the older industrial areas of the world. The iron and steel industry has long been aware of the problems created by surplus slag and, apart from seeking to reduce the amount of slag produced, the industry has put a great deal of effort into finding new uses for what was formerly a waste product. Some of these uses are discussed in this article. Nowadays, slag is regarded as a valuable by-product with an expanding market, and it is produced to consistent standards: at the present time, there is a ready market for all the slag that the industry can produce.

Classification of Slags

General Classification. In very broad terms, slags may be classified in two ways:

(*a*) By the treatment of the slag after it has been tapped from the furnace.

(*b*) By the ingredients of the slag.

Both these factors have an important bearing on the suitability of the slag as an engineering material.

Treatment after Tapping. Slag is taken from the smelting furnace in the molten state and is then allowed to solidify. Since the rate of cooling affects the grain size and porosity, and hence the density and strength, of the solid slag, the treatment of the slag after it has been tapped is of prime importance. Where the slag is regarded as waste, it is merely tipped on to a slag heap, whereas if the slag is to be used as a by-product, it is cooled in controlled conditions. Thus, as regards treatment, the industry divides slag into two main groups: "old tipped slag", ie, that which has been tipped to waste and is to be found in old slag heaps, and "currently produced slag". This article deals mainly with the latter group, which has more uses.

Ingredients. A great many different slags are produced, but very few of them are of interest to the civil engineer. To be of use as an engineering material, a slag must be inert and chemically stable and be available in economic quantities of uniform consistency. Thus the most useful slags are those resulting from the reduction of iron ore and the production of steel. Of these, by far the most plentiful (and thus, from the point of view of this article, the most important) is blast-furnace slag, which is discussed in detail in Parts II and III. Various British Standards refer to the use of steel slags,[1] and it should be noted that where steel slags are to be used as aggregate for road surfacings, a higher binder content is required in the mixes than with other aggregates—this point is also emphasized in the Ministry of Transport

[1] BS 802 of 1958 and BS 1621 of 1961—see Annex "A".

Specification.[1] Comparatively little steel slag is produced—while the slag produced in a blast-furnace is about seven times the volume of the iron obtained, in steel production the proportions are reversed; also, many steel slags have uses outside the scope of this article (eg, Bessemer-steel slag is used as a fertilizer), so that steel slag will not be discussed further.

Old Tipped Slags

Characteristics. The chemical composition of these slags depends on the parent metal and the smelting method, but, because the slag has been allowed to cool under very haphazard conditions, its structure and density will be very variable. Also, the old-fashioned smelting methods, being rather inefficient, may have resulted in there being an unsuitably high metal content in the slag. Without a detailed history of the slag, it may be difficult to determine its composition and hence its suitability for use as an engineering material. B.S. 1047 of 1952—"Air-cooled blast-furnace slag coarse aggregate for concrete", which deals only with iron-based blast-furnace slags, does not differentiate between currently produced slags and those from old tips, but does recommend that the latter be sampled and tested much more frequently than the former.

Availability. At present, the many old slag tips up and down the country contain a great deal of useful slag, mainly that resulting from the reduction of iron and copper ores and many of these tips are being worked as commercial concerns; at other tips, the slag is there for anyone to take away, especially where the local authorities are carrying out land clearance schemes. The method of winning the slag is very similar to conventional quarrying: the slag is dug from the tip (a much easier task than working a rock face) and crushed and graded to the required size. Often, this old slag is sold in the "as dug" state for use as hardcore. However, such old slag heaps, most of which accumulated during the nineteenth century, are a dwindling asset, as nowadays very little useful slag is tipped to waste; in practice, old tipped slag is used mainly as hardcore, slags for more sophisticated uses being obtained from current production. It is of interest to note that in those countries that are now setting up their own iron and steel industries (eg, India) markets already exist for the useable slag by-products.

Use of Old Tipped Slag. Provided that it is of uniform quality and satisfies the appropriate British Standard or other specification, there is no reason why old tipped slag should not be used in the same way as currently produced slag. In the past, the indiscriminate use of old tipped slag, without proper regard to, or control over, its quality, has resulted in the early failure of concretes and road surfacings made with slag aggregate. Even today engineers seem to be very reluctant to use slag aggregate in concrete, although its use in road surfacings is widespread.

PART II—BLAST-FURNACE SLAG

Introduction

So far, we have discussed some of the various types of slag, and have seen that the most important, as far as the civil engineer is concerned, is blast-furnace slag. (From now on, the abbreviation "BFS" will be used.) This section deals with the manufacture of BFS in its various forms.

[1] Ministry of Transport Specification for Road and Bridge Works (1963 Edn) Clause 910, Tables 1, 2 and 3, and Clause 911, Tables 1, 2 and 3.

Slag from Blast-furnaces

The Blast-furnace Process. A blast-furnace is used to reduce iron ore to metallic iron and in so doing a slag by-product is formed. In the process coke, iron ore and fluxes are fed into the top of the furnace. The coke is used to heat the furnace, and also to produce a reducing atmosphere; the iron ore is the raw material and the fluxes, of calcareous and magnesian limestone, are intended both to maintain the fluidity of the slag and to remove, both by absorption and by chemical reaction, those elements that are not desirable in the finished iron. The process is continuous, with the feed materials introduced through a bell in the top of the furnace, the blast air blown in through tuyeres in the lower section, and the iron and slag drawn off at different levels (see Fig. 1). The molten slag, which floats on the denser iron, is drawn off through eyes in the side of the furnace into rail-mounted ladles of up to 20 tons capacity (Photo 1); the slag is taken away in these ladles for further processing.

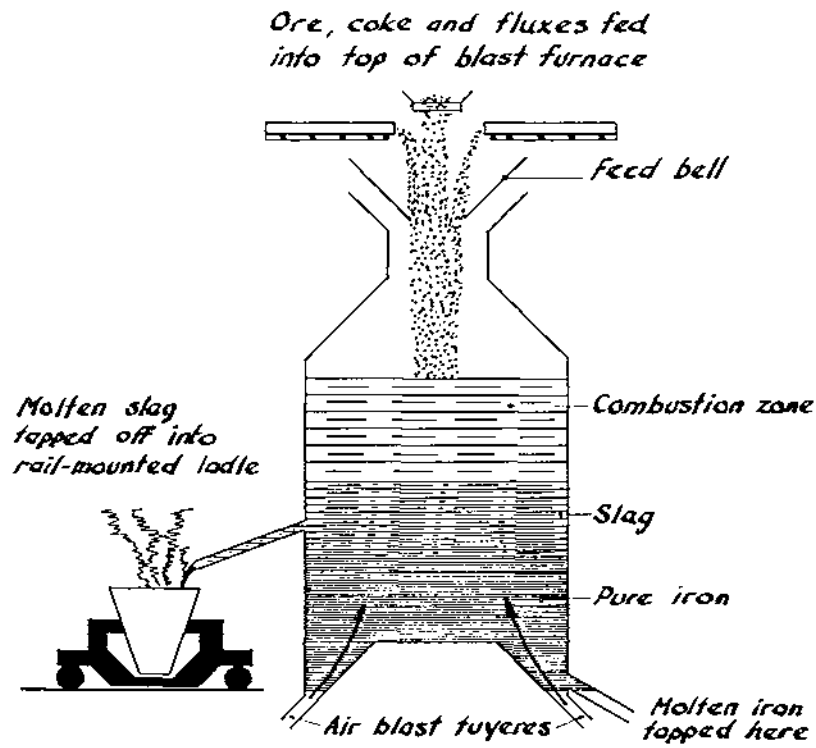


Fig 1. - Diagram of Blast Furnace Process.

The Nature of Blast-furnace Slag. Being the residue of the ore, fluxes and combustion products, BFS is composed of a number of alumino-silicates of calcium and magnesium, minerals that are to be found in some basic igneous rocks. The slag may also contain residual sulphur and iron, and possibly calcium orthosilicates in a form that is liable to undergo volume-change at normal temperatures: the presence of these impurities in appreciable quanti-

Photo 1. A slag cooling bank. The molten slag, which has been brought from the blast furnaces in the 20-ton rail mounted ladles, is tipped down the bank and allowed to cool.

ties will cause the slag to be unstable. Slag is a much more variable material than natural rock owing to its rapid cooling, which results in a great difference in grain size and porosity between the interior and exterior of the cooling masses, the exterior often cooling so rapidly as to form an amorphous glass. Thus in order to maintain a uniform produce, both the chemical composition and cooling conditions of the slag must be carefully controlled.

Chemical Control. The control of blast-furnace efficiency and iron purity is best achieved by accurate control of the slag produced, since it is easier to analyse the slag than the iron, and any elements present in the feed materials and not in the slag must be in the iron. Thus the normal quality control of the blast-furnace process serves to check both the iron and the slag. Nowadays, the producers of BFS so control the blast-furnace process as to produce the best possible slag, consistent with the production of high purity iron. The chemical composition required in the various forms of BFS are laid down in the relevant British Standards, the most important being B.S. 1047; these requirements are summarized in later paragraphs. The impurities in slag which cause the most concern are sulphur, because of its effect on cement, tar and bitumen binders and builders' hardware, and iron, which may cause the slag to disintegrate when iron oxide is formed.

Effect of Cooling Conditions. Solidified slag may be glassy or crystalline, dense or honeycombed, according to the conditions under which it was cooled, and BFS is normally cooled by one of three methods:—

(*a*) *Air-cooling*, which produces a dense, crystalline material suitable for normal aggregates.

(*b*) *Foaming*, which results in a lightweight cellular material suitable for lightweight aggregates.

(*c*) *Ponding*, which produces granulated BFS, in the form of individual amorphous pellets.

These three forms of BFS are described below.

Air-cooled Blast-furnace Slag

Manufacture. Air-cooled BFS is a dense crystalline slag, used mainly as an aggregate for concrete or road sufacings, or as hardcore. It is cooled in one of three ways, depending on the quality required:

(*a*) *Ball Slag.* Ball slag is BFS which has been allowed to cool in the ladle until solid, when it is tipped out and broken down before being crushed in the normal way. Ball slag cools slowly and evenly, and is not disturbed between being tapped from the furnace and solidifying: it thus has a dense and uniform crystalline structure, and is the strongest form of BFS. However, because its manufacture entails taking the ladles out of use for up to forty-eight hours while the slag solidifies, and because of the difficulty of handling a lump of slag weighing up to twenty tons, ball slag is expensive and seldom used.

(*b*) *Pit Slag.* In this form, the molten slag is poured into large shallow pits or canals, and allowed to solidfy in them; the cooling process is hastened by spraying the solid slag with a carefully controlled amount of water which also helps to break up the slag, so that it can be dug out of the pit with normal excavators. This method produces a slag which is almost as good as ball slag, and much cheaper, so that pit slag is the form of air-cooled BFS most commonly used for aggregates.

(*c*) *Bank Slag.* Bank slag is produced by tipping the molten slag down banks so that it lies in shallow layers, and allowing it to cool before removal. The layers are 2–3 in deep, and the product is of a less uniform structure than pit or ball slag; it does, however, have one advantage over the other methods in that the different batches of slag are intermingled on the bank so that if there are excessive impurities in one batch these are "diluted" throughout a large part of the bank, rather than remaining concentrated. If left undisturbed, bank slag takes about eight weeks to cool; this is speeded up by "digging over" the bank, which also serves to keep the rail track carrying the ladles clear for further tipping. A typical cooling bank is shown in Photo 1.

After solidification and cooling, the slag is excavated from pit or bank and crushed in the same way as quarried rock. During the crushing and screening process, the slag is inspected for visual defects and foreign bodies, and metallic iron is extracted by powerful electro-magnets suspended over the crusher feed.

Characteristics. Air-cooled BFS produces a fairly dense, but porous crystalline aggregate, with a very rough texture. As dug from pit or bank, the slag has a cubical shape (Photo 2); crushing produces mainly cubical particles, but some are angular or flaky, particularly the smaller gradings. This is shown in Photo 3, where the slag can be compared with limestone aggregate of the same nominal size. In common with all other currently produced slags, air-cooled BFS is clean, dry and free from organic impurities or any clay or silt content; the crushed aggregate is also fairly dust-free. Air-cooled BFS has the following advantageous characteristics:—

(*a*) Crushes to a generally cubical shape.
(*b*) Low coefficient of expansion.
(*c*) Low specific gravity.
(*d*) High fire resistance (the sintering temperature is 2,200° F).
(*e*) Pitted surface, giving good frictional properties.
(*f*) Alkali content which reduces the tendency of binders to strip when wet.
(*g*) High (0.7) polished stone coefficient.

Photo 2. Pit-cooled blast-furnace slag "as dug". Note the generally cubical shape and rough honey-combed texture.

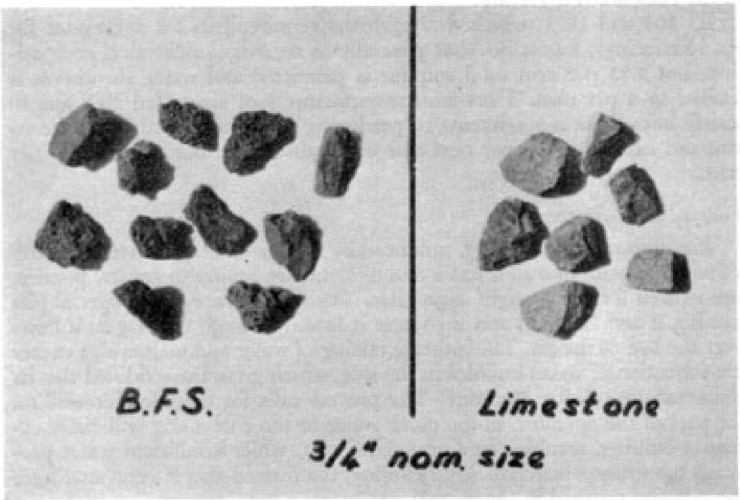


Photo 3. Comparison of air-cooled blast-furnace slag and limestone aggregates of the same nominal size.

Slag As an Engineering material 2,3

The chief disadvantages in its use are that slag, because of its porosity, has a high absorption rate, and also that the slag is subject to some crushing under rolling. However, many authorities hold that the final strength of concrete or tar- or bitumen-macadam is not entirely dependent on the crushing strength of the aggregate, so that the low crushing strength of slag is not a particular disadvantage.

Requirements. It is generally considered that a material made with slag aggregate is more likely to fail because of the instability of the slag than its low crushing strength, and the British Standards requirements for the chemical stability of air-cooled BFS aggregate for concrete are set out in B.S. 1047. These requirements are summarized below:—

(*a*) *Sulphur Unsoundness.* Chemical analysis should show that the acid soluble sulphate, expressed as SO_3, is less than 0.7 per cent and the total sulphur does not exceed 2.0 per cent.

(*b*) *Iron Unsoundness.* The slag shall be free from signs of disintegration after soaking in water for fourteen days.

(*c*) *"Falling", "Dusting" or "Lime" Unsoundness.* If the chemical composition of the slag satisfies either of the following conditions, it is regarded as free from this type of unsoundness:—

$$(\%CaO) + 0.8(\%MgO) \leqslant 1.2(\%SiO_2) + 0.4(\%Al_2O_3) + 1.75(\%S)$$

or

$$(\%CaO) \leqslant 0.9(\%SiO_2) + 0.6(\%Al_2O_3) + 1.75(\%S)$$

Slags that fail to satisfy either of these requirements are further tested by microscopic examination of etched polished surfaces, unstable slags being distinguished by characteristic markings.

(*d*) *Porosity.* This is controlled by specifying an upper limit of 10 per cent for water absorption and a lower limit of 79 lb for the weight of a cubic foot of the compacted aggregate.

BS 802 and 1621, which deal with the requirements for aggregates for road surfacings, follow BS 1047 generally as regards the chemical composition, but 2.75 per cent total sulphur is permitted and water absorption is limited to 4 per cent. Thus most manufacturers of air-cooled BFS aim to satisfy both these requirements by producing slag with a total sulphur content not exceeding 2.0 per cent and water absorption not exceeding 4 per cent.

Foamed Blast-furnace Slag

Manufacture. Foamed slag, produced by rapidly chilling molten BFS with a limited amount of water, has a porous structure similar to natural pumice, and is used for light-weight aggregates. The slag is processed in special pits (see Fig. 2 and Photo 4) and the water is forced through the slag as it flows over the bed of the pit. The intimate mixing of water and molten slag causes the formation of steam bubbles in the slag, which gives the solidified slag its characteristic cellular structure. The process calls for considerable skill on the part of the operator, as too much water or too cool a slag will cause excessive chilling, resulting in a granulated slag, while insufficient water produces too dense a material. After chilling, the foamed slag is excavated from the pits and crushed in the normal way.

Characteristics. Foamed BFS has a light-weight, cellular structure and consists mainly of alumino-silicates of lime and magnesium in a glassy, partly

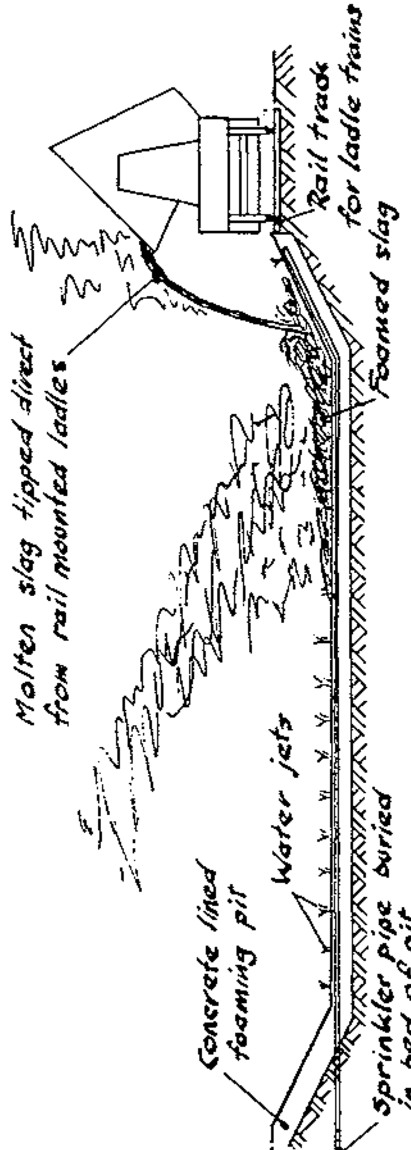


Fig 2. - The slag foaming process.

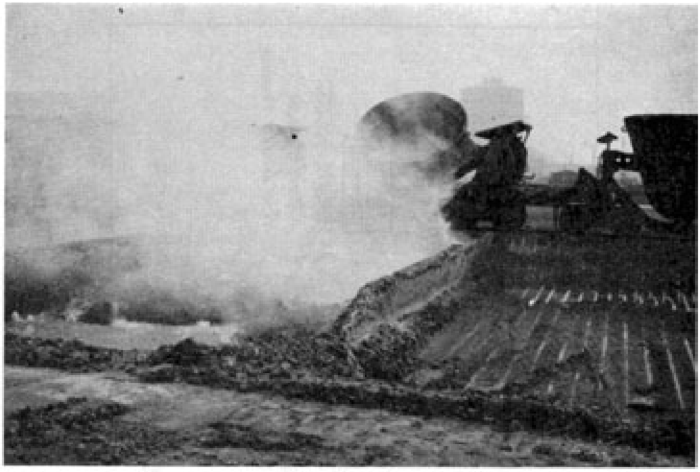


Photo 4. The making of foamed slag.

Photo 5. Foamed blast-furnace slag as dug from the foaming pit. Note the random shape of the pieces of slag compared with air-cooled slag (Photo 2).

crystalline or crystalline condition. As dug from the foaming pits, the slag is very random in shape and size (see Photo 5) but crushing and screening produces an aggregate of irregular or cubical shape with a very rough surface. The properties of foamed slag are similar to those of air-cooled BFS; in addition, foamed slag has extremely good thermal insulation properties and a light weight.

Requirements. As with air-cooled BFS, the main criterion is the chemical stability of foamed slag. The requirements for its chemical composition are laid down in BS 877 of 1939—"British Standard Specification for foamed blast-furnace slag for concrete aggregate",[1] and are summarized below:—

(*a*) *Lime Content.* The BFS used in the manufacture of foamed slag shall have a lime content not exceeding 50 per cent by weight.

(*b*) *Density.* The bulk density of the crushed foamed slag shall not be greater than 42 lb/cu ft.

(*c*) *Stability (Free Iron Content).* The slag shall be free from signs of disintegration after soaking in water for fourteen days, and the loss in weight shall not exceed 1 per cent.

(*d*) *Sulphur Content.* The sulphur content, expressed as SO_3, shall not exceed 0.5 per cent.

(*e*) *Contamination by Coke.* The loss on ignition shall not exceed 2 per cent by weight.

(*f*) *Heavy Impurities.* If the BFS used in the process does not comply with BS 1047, the content of heavy impurities shall not exceed 10 per cent by weight.

(*g*) *Additives.* Only slag produced as a by-product in the manufacture of pig-iron in the blast furnace shall be used, and no additives to the slag, other than the water used for foaming, are permitted.

The methods of sampling and testing foamed BFS aggregates are set out in BS 3681 of 1963—"Methods for the sampling and testing of light-weight aggregates for concrete".

Granulated Blast-furnace Slag

Granulated slag is produced by pouring the molten BFS into pools of water. This chills the slag so that pellets of an amorphous material are formed. The main use for granulated BFS is in the manufacture of Portland-Blast-furnace Cement, where the granulated slag is usually added to the cement clinker just before the final grinding process. The requirements for Portland-Blast-furnace Cement are given in BS 146 of 1958—"Portland-Blast-furnace Cement", which limits the proportion of granulated BFS in the cement to not more than 65 per cent by weight of the whole. The properties of blast-furnace cement are very similar to those of normal Portland Cement, but it evolves less heat on hydration and is slightly more resistant to chemical attack.

Natural Cementicious Properties of Blast-furnace Slag

Table 1 compares the chemical composition of a typical BFS with that of normal Portland Cement, and it can be seen that the main oxides present in both are the same, and in roughly the same proportions.

[1] BS 877 was the first British Standard to be issued on the subject of slag, and foamed slag is the only light-weight concrete aggregate to have a British Standard devoted solely to it.

TABLE 1. *Comparison of the chemical composition of Blast-furnace Slag and Portland Cement*

Main Oxides (% composition)	Air-cooled BFS (to BS 1047)	Portland Cement (to BS 12)
CaO	40	64
SiO_2	33	21
Al_2O_3	15	6
Fe_2O_3	0.7	3
MgO	8	—
Trace elements	3.3	6

Thus all forms of BFS exhibit natural cementicious properties, but it is only when the slag is finely divided, as in Portland-Blast-furnace Cement, that this property can be fully exploited—the fine division of the slag is necessary for hydration by allowing intimate contact between the water and calcium silicates. The cementicious properties of BFS are also used in water-bound macadams made with slag aggregate.

PART III—SOME USES OF BLAST-FURNACE SLAG

Introduction

This part of the article describes some of the main uses of BFS: these are concrete, both normal and light-weight, road construction and filter media.

Normal Concrete

General. Provided that it is sound and stable (ie, that it complies with BS 1047), there is no reason whatsoever why plain or reinforced concrete made with BFS aggregate should be any different to that made with natural aggregates. It is normal to use slag as the coarse aggregate only, the fine aggregate being mineral sand, but fine slag aggregate may also be used. Some notes on the properties of concrete made with air-cooled BFS aggregate are included at Annex "B". (These notes are reproduced from BS 1047.) One of the main advantages of slag aggregate is that, being produced in conditions of intense heat, it has a higher resistance to fire than most natural aggregates, especially those containing free silica (eg, gravel).

Sulphates. The use of slag aggregates having a higher sulphate content than that permitted by BS 1047 is not advisable, as the sulphur may cause the concrete to disintegrate. Therefore, old tipped slags are seldom used for concrete work. The use of a sulphate-resisting cement may overcome this, but little research has been done on the ability of these cements to counter the effects of sulphur which is present in the aggregate, as opposed to external attack by sulphates (eg, in ground water), and at present there is no British Standard on sulphate-resisting cements.

Reservations in the Use of Slag in Concrete. Notwithstanding remarks in preceeding paragraphs and Annex "B", there is still a marked reluctance among civil engineers to use slag as a concrete aggregate, particularly for structural work, and the MOT Specification, in Clause 2903—"Aggregates for Concrete", permits its use only in *non-structural* concrete. This reluctance stems in part from the past use of unsatisfactory slags, but in the main it appears to be due to a fear of the effects of strange chemicals in the slag, particularly sulphur. Civil engineers are not usually renowned for their knowledge of chemistry, and the view of the slag industry is that "civil engineers should forget what little chemistry they think they know, and rely on the expert advice of such bodies as the British Standards Institute and the Cement and Concrete Association". Certainly the main slag producers are doing their best to popularize the use of slag-aggregate concrete, and much of the Appleby-Frodingham Steelworks was constructed of this. Photo 6 shows part of a new crushing and screening plant which is being erected at the Steel Company of Wales' Margam Slag Works; the concrete used is made with an all-slag aggregate.

Gradings. Air-cooled BFS aggregates for concrete are normally produced to the gradings specified in BS 1047 and shown in Table 2, but may be supplied to other sizes if the customer so requires.

TABLE 2. *BS Gradings for air-cooled BFS coarse aggregates for concrete*

BS sieve mesh (inches)	Graded Aggregate			Single-sized Aggregate ("no-fines")
	$1\frac{1}{2}$–$\frac{3}{16}$ in	$\frac{3}{4}$–$\frac{3}{16}$ in	$\frac{1}{2}$–$\frac{3}{16}$ in	$\frac{3}{4}$ in
	% passing	% passing	% passing	% passing
$1\frac{1}{2}$	95–100	100	—	—
$\frac{3}{4}$	30–70	95–100	100	100
$\frac{1}{2}$	—	—	90–100	—
$\frac{3}{8}$	10–35	25–55	40–85	0–5
$\frac{3}{16}$	0–5	0–5	0–5	—

Light-weight Concrete

Introduction

Ligh-tweight concrete may be defined as concrete having a density less than 120 lb/cu ft, as opposed to normal concrete, made with dense aggregates, and having densities from 135 to 150 lb/cu ft. The use of light-weight concrete in building and civil engineering, both for structural and non-load-bearing purposes, is growing and foamed BFS, to BS 877, is the most widely used light-weight aggregate in the UK at the present time. Comparable aggregates are clinker, which is becoming scarce and, because of its high sulphur content, may not be used in contact with steelwork, and pumice which must be imported.

Characteristics of Foamed Slag Light-weight Concrete

(*a*) *Structure and Surface Texture.* Foamed slag lightweight concrete (abbreviated to FSLC) is usually made using both coarse and fine slag aggregates, although sand may be used for the fines, and thus the concrete consists of the cellular foamed slag aggregate bound together in a matrix of cement and slag fines, causing the concrete to have a voidage which can be varied with the mix proportions. The surface texture is normally rough and open (see Photo 7), but the denser mixes, particularly those with a higher fines content, may have a smooth surface resembling that of normal concrete. The open texture provides a good key for applied wet finishes.

(*b*) *Density and Compressive Strength.* The density of FSLC, which is dependent on the cement content, aggregate grading, water/cement ratio and

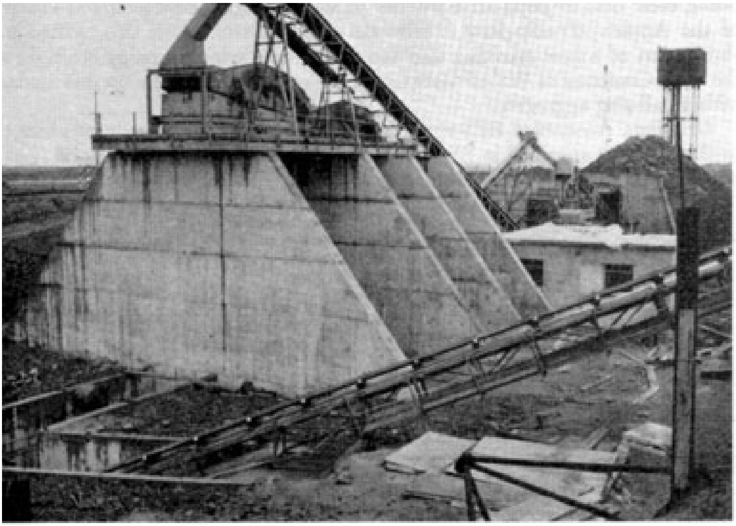


Photo 6. Structural concrete made with slag aggregate.

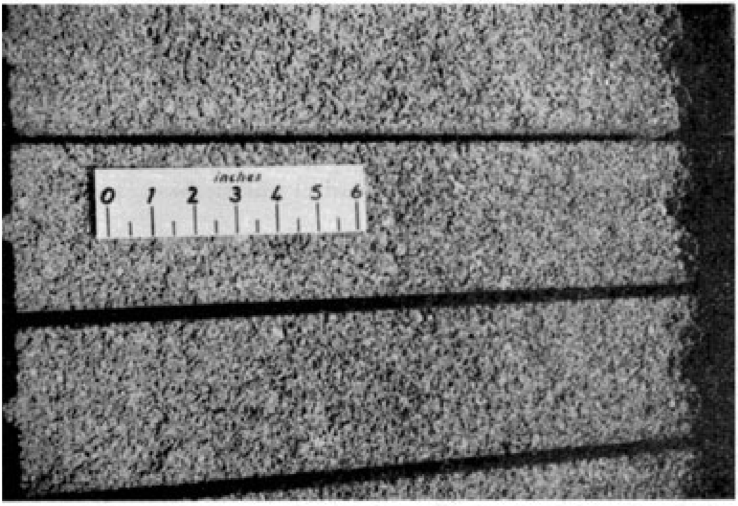


Photo 7. Precast lightweight concrete building blocks made with foamed slag aggregate. Note the rough, open surface texture of semi-compacted foamed slag concrete.

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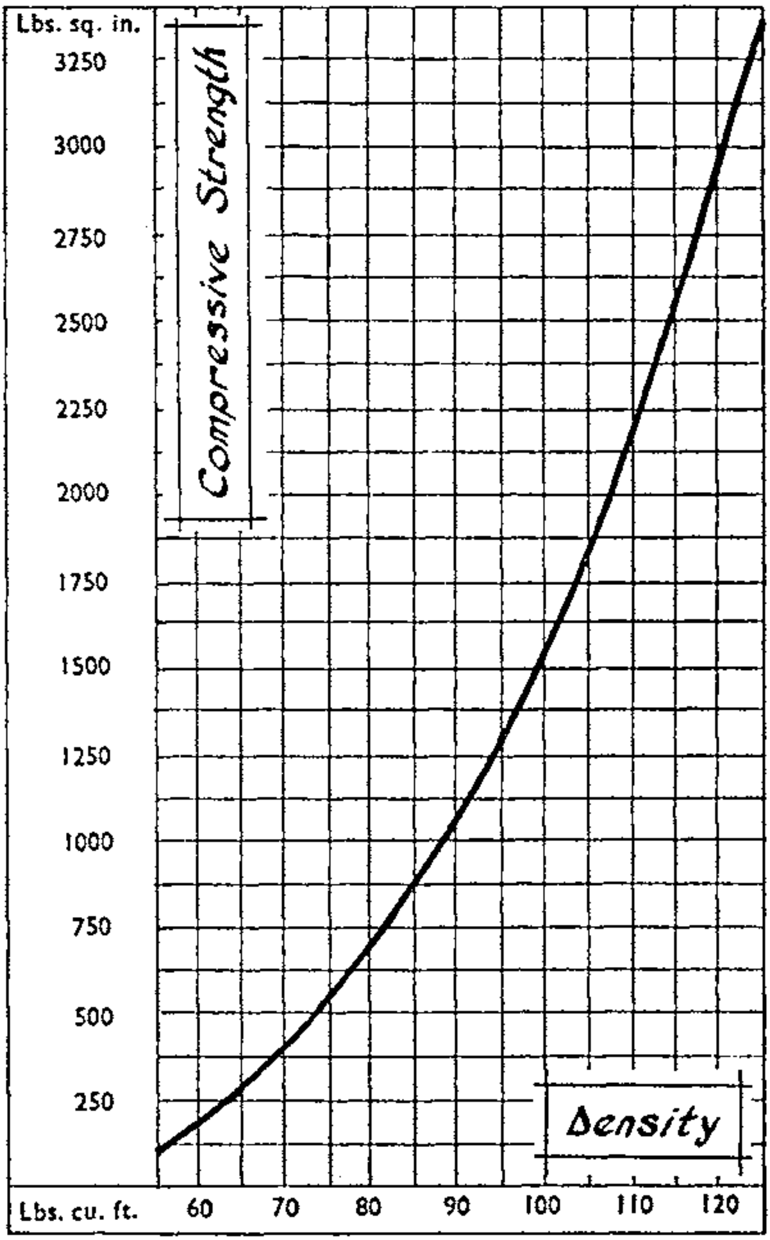

Fig 3. The approximate relationship between the compressive strength and density of Foamed Slag Concrete.

the degree of compaction of the wet mix, can be varied from about 60 lb/cu ft up to 120 lb/cu ft. Its compressive strength is closely related to its density, but the actual mix design also effects the strength, so that FSLC can be made with the same density but different strengths and vice-versa. Compressive strengths vary from about 250 lb/sq in at 60 lb/cu ft up to 5,000 lb/sq in at 120 lb/cu ft, and the approximate relationship is shown in Fig. 3. The natural cementicious properties of BFS are particularly apparent in FSLC, so that appreciable rises in strength occur after the normal maturing period.

(*c*) *Effect on Metals.* The alkalinity of foamed slag tends to prevent corrosion of embedded ferrous metals, and the sulphur content of the slag is limited to 0.5 per cent.

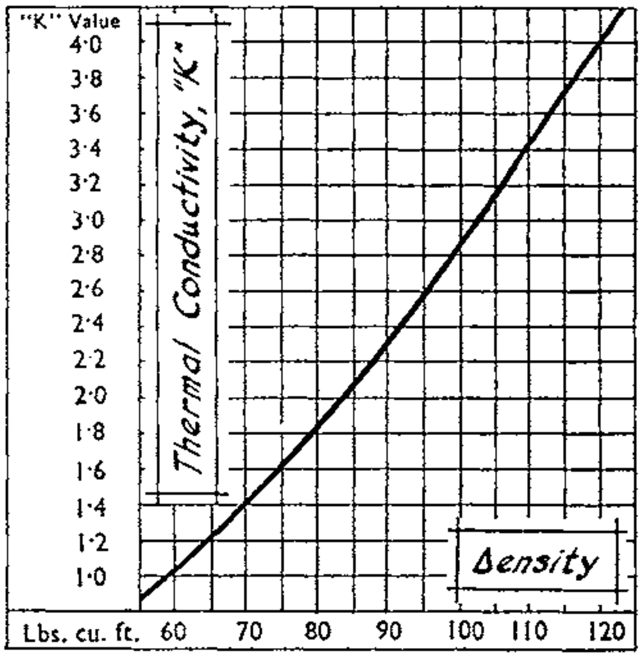

Fig 4. The approximate relationship between the thermal conductivity and the density of Foamed Slag Concrete.

(*d*) *Thermal Insulation and Fire Resistance.* Because of its cellular structure, FSLC has good thermal insulating properties. The less dense mixes obviously give the better insulation, but even for structural FSLC, with densities from 100 to 120 lb/cu ft, the "k" values are between 3 and 4, compared with 9 or 10 for normal concrete. Fig 4 relates the density and thermal conductivity of FSLC. In common with air-cooled BFS, FSLC has a very high resistance to fire, and there is no spalling or disintegration of the aggregate under conditions of intense heat; the thermal insulation properties

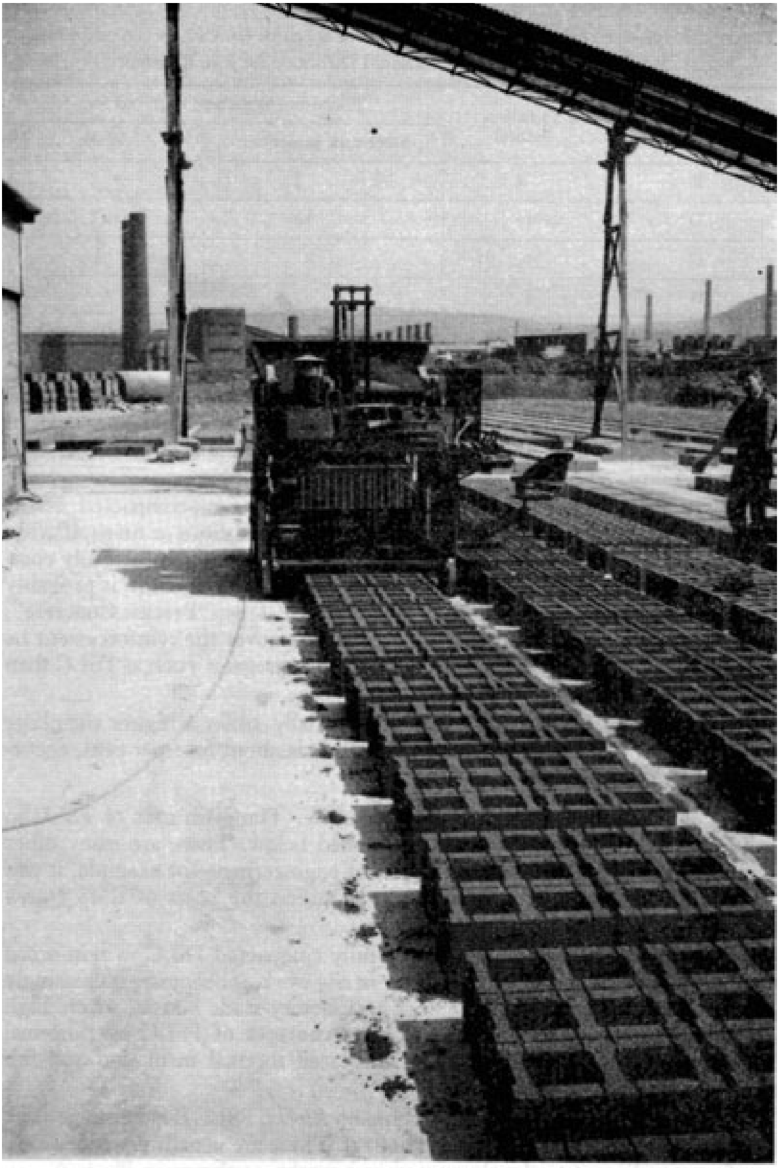

Photo 8. Typical view of a production line for the large-scale manufacture of precast light-weight concrete blocks.

afford good protection to structural steelwork. Table 3 shows the thicknesses of FSLC required for various fire ratings, and foamed slag aggregate is rated "A1" for fire resistance (a distinction shared only with natural pumice).

TABLE 3. *The thickness of Foamed Slag Concrete required to provide protection for various fire ratings* (to B.S. 476 of 1932—'British Standard Definition for Fire Resistance')

Grade of Resistance	Duration (hours)	Thickness (in inches) required for:	
		Steelwork protection	Walls
E	½	½	—
D	1	1½	2
C	2	2	3½
B	4	3½	4½–5
A	6	4½–5	5½–6

(*e*) *Workability.* In common with other slag concretes, FSLC tends to be harsh working; the richer or wetter mixes, or those with higher fines content are the easier to work. The use of sand in place of the slag fines increases the workability.

(*f*) *Weather Resistance.* The open texture of semi-compacted FSLC permits limited penetration of rain, but since there is little or no capillarity, this penetration is limited to the outer inch or so of the concrete. Fully compacted high strength FSLC, with a density exceeding 100 lb/cu ft, is probably as impermeable as normal concrete. However, CP 116—"Precast Concrete", recommends (in section 3M) that ½ in more cover over the reinforcement be provided when using light-weight permeable aggregates such as FSLC than would be necessary in normal concrete practice.

(*g*) *Shrinkage.* Light-weight concretes usually suffer a higher shrinkage than normal concrete; the shrinkage for FSLC is about 0.04 per cent, occurring within fourteen days.

Uses of Foamed Slag Light-weight Concrete. The main uses of FSLC in building and civil engineering are mentioned below. There are many other uses for this material, in many branches of engineering—for example, it was used, sandwiched between steel plates, to stiffen the bows of RMS *Queen Mary*.

(*a*) *Structural Concrete.* The use of fully compacted FSLC in reinforced structural elements, either precast or for *in situ* work, is becoming increasingly popular, particularly in building work and factory-made houses, where high strength concrete is not required. The advantages of FSLC over normal concrete are reduced deadloads and increased thermal insulation and fire resistance.

(*b*) *Precast Light-weight Concrete Masonry Blocks.* FSLC is an ideal medium for light-weight precast blocks (see Photo 7). These are usually machine-made in a factory adjacent to the slag processing works, as shown in Photo 8.

(*c*) *In situ Concrete Walls.* FSLC is particularly suitable for large repetitive housing schemes in forming low-cost insulating, light-weight external and internal *in situ* walls and partitions.

(*d*) *Casing of Structural Steelwork.* The advantages of using FSLC to provide fire protection for structural steelwork were discussed earlier, and when used as a casing, the concrete may be applied either as precast units or an *in situ* rendering.

(*e*) *Curtain Walling and Prefabricated Structures.* FSLC is used extensively as the core or backing for preformed decorative facings, thus saving weight and providing good thermal insulation and a high bond strength to the facings.

(*f*) *Light-weight In-fill.* In bridge and viaduct construction, where the deck is formed with precast beams, FSLC is often used as a in-fill between the beams and to form the deck profile. Another use is for light-weight floor and roof screeds, where FSLC provides thermal insulation and fire resistance, as well as forming falls and embedding services; because the aggregate is friable, a ½ in topping of sand mortar is needed.

Gradings. Foamed slag concrete aggregate is usually supplied in the following gradings (to BS 877): Coarse, from ½ in to ⅛ in, and Fine, from ⅛ in down.

Storage of Aggregates. Foamed slag is resistant to weathering, and coarse aggregate may safely be stored in the open; the cementicious properties of the slag, however, will cause the fines to become lumpy, and fine aggregate should be stored under cover.

Road Construction

General. Nearly every part of a road can be made with slag, from the sub-base to the wearing course. Fig. 5 shows the construction details of a typical flexible-surfaced heavy duty road, and the use of slag in the various parts is discussed in succeeding paragraphs.

Subgrade. Slag is often used as an imported fill in the construction of the road formation. Either bank-cooled BFS or old tipped slags are used and the slag is normally supplied "as dug". The best method of compaction is to place the slag in 6 to 9 in layers and compact it with heavy tracked plant—the churning and crushing action of the tracks serves to compact the slag into a firm dense mass. Even so, there are sufficient voids present to provide excellent drainage. Not least among the advantages of using slag fill is that its lower density (78 lb/cu ft compared with 120 to 130 lb/cu ft for limestone hardcore or 110 to 120 lb/cu ft for soil) means lower transport costs; the other chief advantages are that slag, being clean, dry and inert, is immediately stable and is unaffected by weather, so that it is not necessary to provide a weathering layer above formation level, which must be removed just before the sub-base is laid.

Drainage. Where subsoil drains are required, as in cuttings, no-fines concrete, made with single-size slag aggregate is frequently used.

Sub-base. Slag has been used as a granular sub-base material but, in the Author's experience, it is not wholly successful: unless the slag is very well graded and compacted, it tends to roll under wheeled traffic and the surface becomes churned-up. Also, the slag is difficult to handle if segregation of the fines is to be avoided.

Haunches and Kerb Foundations. Haunches (a typical example is shown in Fig. 5) and kerb foundations require a medium strength concrete, and air-cooled BFS, to BS 1047, is suitable for this.

Road Base. The base is usually composed of lean-mix concrete, wet- or dry-bound macadam, or tar- or bitumen-bound material. Slag aggregates, to BS 1047, can be used for all of these:

(*a*) *Lean-mix Concrete.* The requirements for a lean-mix concrete base are laid down in Clause 806 of the MOT Specification: the cement/aggregate ratio is between 1 : 20 and 1 : 15, to produce 28-day strengths of not less than 1,400 lb/sq in, and the compaction should be such as to allow not more than 5 per cent air voids.

(*b*) *Pre-mix Waterbound Macadam.* Slag is an ideal material for waterbound macadam bases, since the cementicious properties of the slag produce a form of lean concrete. In order to exploit these properties, it is normal to use a higher proportion of fines (up to 10 per cent passing No. 22 sieve) in the slag than in other aggregates. (MOT Specification Clause 807.)

(*c*) *Dry Macadam and Tar- and Bitumen-bound Bases.* These are covered in Clauses 808, 809 and 810 of the MOT Specification. BFS has a greater affinity for bitumen binders than for tar, and tar-bound slag bases are seldom used.

Surfacing. The subject of flexible road surfacings is a very wide one, and outside the scope of this paper. The main types of surfacing in which slag aggregate may be used are listed in Table 4:—

TABLE 4. *Main types of Flexible Road Surfacings*

Serial No	Surfacing	Uses	Relevant Clause of MOT Specification	Appropriate BS (Annex "A")
1	Tarmacadam and "Tarpaving"	Wearing and base course for light and medium duty roads. Cycle tracks, footpaths and playgrounds.	907, 908, 917, 918 and 923	802/58 1242/60
2	Dense Tarmacadam	Wearing and base course for medium and heavy duty roads. Cycle tracks.	903 and 911	802/58 1242/60
3	Bitumen Macadam	As for Serial 1	904, 909, 917 and 918	1621/61
4	Dense Bitumen Macadam	As for Serial 2	905, 910 and 917	1621/61
5	Cold Asphalt	Wearing course for light, medium and heavy duty roads. Cycle tracks and footpaths.	906, 917, 918 and 923	1960/62
6	Hot Rolled Asphalt	Wearing course for medium and heavy duty roads. Base course for heavy duty roads. Cycle tracks.	901, 902, 912 and 923	594/61

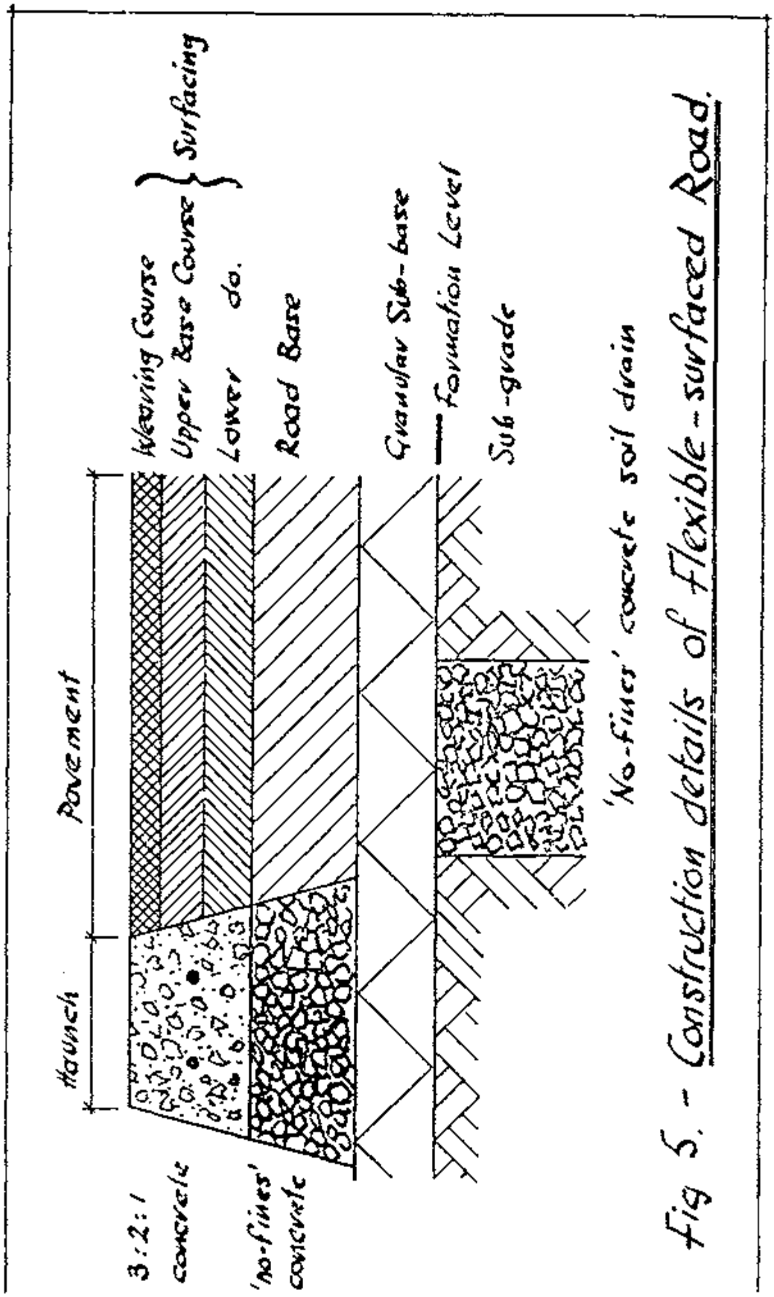

Fig 5. - Construction details of Flexible-surfaced Road.

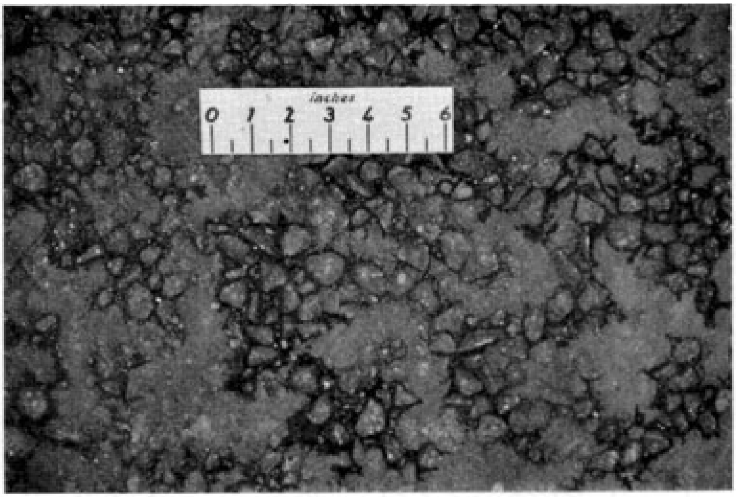

Photo 9. Hot rolled asphalt wearing course with $\frac{3}{4}$ in coated chippings. Both the aggregate and chippings are air-cooled blast-furnace slag.
(Port Talbot By-Pass.) (MOT Spec Clause 901.)

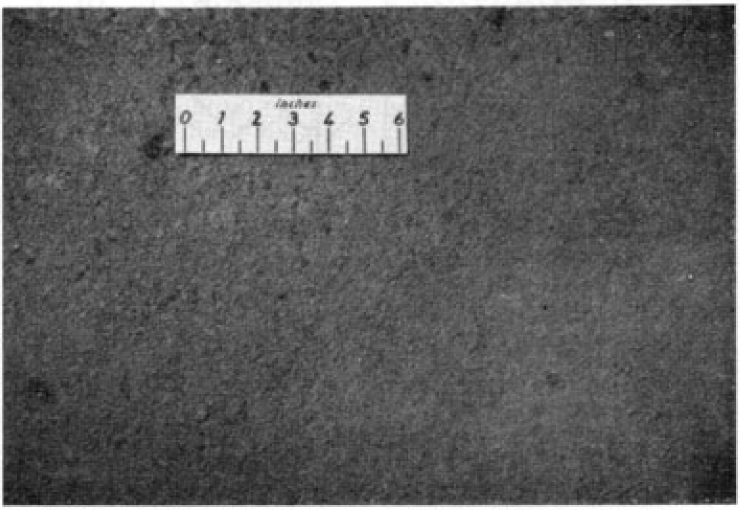

Photo 10. $\frac{1}{2}$ in thick fine cold asphalt wearing course laid direct on pre-mix waterbound slag macadam base.

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Air-cooled BFS is an excellent material for road surfacings and is almost the only aggregate used for cold asphalt and dense bitumen macadams. Particular advantages of slag are its high polished stone coefficient and its low density, giving increased coverage per ton of material. As with bases, the best results are achieved with bitumen, rather than tar binders. However, it should be noted that it is not possible to achieve full compaction of slag-aggregate surfacings by rolling alone and some compaction under traffic must be expected. Photo 9 shows an example of Hot Rolled Asphalt surfacing made with slag aggregate and bitumen binders.

Low-cost Roads. Slag has been used successfully in the construction of low-cost roads. One example of this, of which the Author has personal knowledge, is used in factory roads at the Steel Company of Wales' Port Talbot plant. The base consists of pre-mix waterbound slag macadam and is 12 to 18 in thick, depending on the nature of the subgrade. This base is sealed with a ½-in thick wearing course of fine cold asphalt, to BS 1960. Air-cooled BFS aggregate is ideal for such a thin wearing course, as it has high mechanical strength and resistance to stripping, and good wearing properties; Photo 10 shows the surface of such a road, which has been in use for several years under consistently heavy traffic.

Other Uses of Blast-furnace Slag

Railway Track Ballast. BFS has been used for many years as ballast for railway tracks, both on the Continent and in this country, particularly in British Rail's Eastern region, where natural ballast is scarce. However, there are certain disadvantages in using slag for this purpose: stag ballast is difficult to pack by hand and tends to shatter when packed by machine. Also, because of its porous texture, the slag retains dust and weed control is more difficult.

Filter Media. Biological filter media, such as those used in sewage disposal plants, should have the following properties:—

(*a*) *Durability.* The media should be both mechanically and chemically durable, ie, resistant to crushing under its own weight, breakage during transport and handling, and to chemical attack.

(*b*) *Size and Shape.* The particles of the medium should be of uniform size and angular shape, so that the maximum voids are present to permit the passage of air and to prevent clogging of the filter.

(*c*) *Cleanliness.* The filter media should be clean and free from dust, fines and organic matter.

(*d*) *Surface Texture.* The surface texture should be rough so as to present the maximum surface area to support the biological film.

These requirements are set out in BS 1438 or 1948—"Media for Biological Percolating Filters", which recommends BFS as a suitable medium.

Marketing of Slag

Currently produced slags are marketed by the processing companies, which are all subsidiaries of the major iron and steel concerns—often, these subsidiaries are jointly owned by large civil engineering firms. Many of the slag companies, in addition to processing the slag, also manufacture foamed slag concrete blocks and blacktop surfacings. Large users buy their slag direct from the producers, or their distributors, but small quantities are distributed through builders' merchants.

Cost. The cost of currently produced slag aggregate, at the processing plant, is generally about 3*s* per ton less than natural aggregate, and as the volume of a ton of slag is some 30 per cent greater than a ton of natural aggregate, the saving can be considerable. However, since slag is produced only in certain parts of the UK (mainly Clydeside, north east England, the Midlands and South Wales), the cost of slag delivered to site may well be greater than that of local materials.

Trade Federations. The two main trade federations are:—The British Slag Federation, 69/73, Theobalds Road, London, WC1, and The Foamed Slag Producers' Federation, 14 Carteret Street, London, SW1. Both of these bodies publish technical literature and will give assistance to users of slag.

Military Applications

Permanent Works

The use of slag in permanent works has been covered in the preceeding sections of this article.

Operational Works

Operational works are usually of a temporary nature, so that less stable slags may be used, as disintegration is unlikely to occur during the life of the project: this means that old tipped slags could be used for all purposes. Some particular uses of slag which may be of benefit to the military engineer are discussed below.

Rapid All-weather Road Construction. The type of road construction described under "Low Cost Roads" could well be exploited as a rapid method of building all-weather roads in operational areas. As well as speed, this method offers a considerable saving in the amount of surfacing required.

Hardcore Fill. An army on the move uses huge quantities of hardcore for fill and slag is ideal for this—its light weight reduces the transport requirements. A particular use for slag fill might well be in the construction of bridge approaches and roads across marshy land, where its low density, good frictional properties and immediate stability can be used to the best advantage. The Dutch have used a form of semi-foamed slag, called "Hüttenbims" (lit. "ironworks pumice") for the construction of dykes and banks in their polder reclamation schemes.

Availability. No material, however good, is of much use unless it is readily available, and the military engineer can only expect to find slag, especially old tips, in the older industrial areas or in the immediate vicinity of iron or steel works. However, if it is necessary to import aggregates or hardcore to an operational area, there are certain advantages in using slag for this: it is light and most of the slag producing areas in the UK are near seaports.

Conclusions

Blast-furnace slag is an accepted engineering material, particularly for road construction and light-weight concrete; however, it has yet to become popular as an aggregate for normal concrete. Provided that the slag complies with the appropriate British Standard, there are no restrictions on its use, but old tipped slags should be used with caution.

Acknowledgement

The author wishes to acknowledge his thanks to the following organizations for their help in preparing this article:

The British Standards Institution; The British Slag Federation; The Foamed Slag Producers' Federation; The Margum Slag Co Ltd; The Steel Company of Wales Ltd.

Annexure "A"

Bibliography

The following reference works cover one or more aspects of the use of slag as an engineering material:

British Standards

12 of 1947	Portland cement (ordinary and rapid-hardening)
146 of 1958	Portland-blast-furnace cement
476 of 1932	British Standard Definition for fire resistance
594 of 1961	Specification for rolled asphalt (hot process)
598 of 1958	Sampling and examination of bituminous mixtures for roads and buildings
802 of 1958	Specification for tarmacadam with crushed rock or slag aggregate
812 of 1960	Methods for the sampling and testing of mineral aggregates, sands and fillers
877 of 1939	Specification for foamed blast-furnace slag for concrete aggregate
1047 of 1952	Air-cooled blast-furnace slag coarse aggregate for concrete
1242 of 1960	Tarmacadam "Tarpaving" for footpaths, playgrounds and similar works
1438 of 1948	Biological percolating media
1621 of 1961	Specification for bitumen macadam with crushed rock or slag aggregate
1960 of 1962	Specification for cold asphalt
3681 of 1963	Methods for sampling and testing light-weight aggregates for concrete
CP116 of 1965	The structural use of precast concrete

(British Standards are obtainable from the British Standards Institution, 2 Park Street, London, W1. Regional libraries holding reference sets of the standards are listed in the Institution's *Yearbook.*)

Road Research Laboratory Publications

Soil Mechanics for Road Engineers (ME Vol V, Part II), especially Chapter 6.

Concrete Roads—Design and Construction.

Road Note 20—"Construction of Housing Estate Roads".

Road Note 26—"Private Street Works".

Road Note 29—"Guide to the structural Design of flexible and rigid pavements for new roads".

Ministry of Transport Publications

Specification for Road and Bridge Works (1963 Edn), especially Sections 8, 9 and 29.

Technical Memorandum No. T 3/63, dated 31 December 1963.

Annexure "B"

A Note on the Properties of Concrete Made With Air-cooled Blast-furnace Slag Aggregate

(Reproduced from Appendix G to BS 1047 of 1952—"Air-cooled blast-furnace slag coarse aggregate for concrete".)

The following notes on the properties of concrete made with blast-furnace slag aggregate complying with this specification are for the assistance of users who may be less familiar with this type of aggregate than with natural aggregates.

Concrete mixes with slag aggregates, like those with crushed rocks, tend to be somewhat harsher than mixes with gravel and sand and a slightly increased water content may be required to obtain an equivalent workability. For example, with a 1 : 2 : 4 by weight mix, a water/cement weight ratio of 0.60 was required with a good quality washed gravel and sand to obtain a certain workability; with slag coarse and fine aggregate the value varied from 0.65 to 0·70 with different slags; and with a slag coarse aggregate and a natural sand fine aggregate the corresponding range was from 0.60 to 0.65.

As with other aggregates more mixing water is required as the absorption of the aggregate approaches the upper permissible limit. The apparent specific gravity of slag aggregates complying with this specification will often be slightly higher than that of gravel and sand. In consequence, despite any slight increase in water content of the mix, the weight per cubic yard of the concrete may be slightly greater. This will also result in a slight increase in the cement content per cubic yard of concrete, the increase varying from about 0 to 4 per cent when proportioning is on a weight basis, and by a slightly larger amount when aggregates are proportioned by volume and cement by weight.

Concretes made from coarse and fine slag aggregates tend to be somewhat slower in hardening than those made from best quality washed gravel and sand, and for mixes of similar proportions and equivalent workability the compressive strength at early ages is somewhat lower. There is less difference in hardening time when the aggregate is made up of slag coarse aggregate and natural sand fine aggregate. The ultimate strength for each type of mix is on the average similar to that for the gravel-sand concrete. It is emphasized that this comparison is based on tests made on a washed and graded gravel-sand aggregate which is probably superior to the average run of materials in use, and that when compared with the latter the strengths at early ages of the slag aggregate concretes would show less, if any, difference.

The dimensional changes, that is shrinkage and expansion of slag concretes made with aggregates complying with this specification do not differ in any significant way from those of gravel and sand concretes. Slag concretes have, however, a rather higher water absorption than comparable gravel concrete mixes of equivalent workability, eg, the absorption of a particular gravel-sand concrete was 6.3 per cent by weight while that of the slag concretes varied from 7.2 to 9.8 per cent. In this respect they are again comparable to many crushed rocks.

The fear has often been expressed that slag aggregates may cause corrosion of steel reinforcement. It has, however, been found from numerous tests, both abroad and in this country, that the use of slag does not introduce any new cause of corrosion not present with other aggregates. Provided therefore that the same precautions are taken to obtain a properly consolidated concrete, and adequate cover to the reinforcement as are necessary with gravel or other aggregates there is no additional risk of corrosion.

Concretes made with slag aggregates have an advantage over those made with gravel and other aggregates containing free silica in their resistance to fire which, with the latter, often causes spalling and a considerable loss in strength. Amongst the heavy aggregates, crushed dense burnt clay bricks have usually been considered to produce the most fire-resistant concretes, but slag aggregates show properties very similar to those of the crushed brick.

Nepal Trek 1964

By Lieut-Colonel T. C. White, RE

One of the privileges of serving in the Brigade of Gurkhas is that of being able to visit Nepal. A limited number of British officers are allowed to visit the country when on leave in order to improve their knowledge of the Gurkha soldier and to learn something of his country and his home background. At the same time this allows the people of Nepal to have a look at them. The opportunities to go to Nepal on duty occur only rarely and I was fortunate to make a visit in this way in October and November 1964.

We set off on the first part of our journey from Singapore. Myself, Major Gil Roach, and Staff Sergeant Bhimbahadur Gurung: Bhimbahadur was going home to Nepal on leave and had offered to accompany us as a guide because we were to trek in a part of the country that he knew well. We flew from Singapore to Calcutta in an Air India 707. This was a charter flight carrying Gurkha soldiers and their families back to India on their way home on leave.

It was seventeen years since I had last been in Calcutta and I found it less pleasant now than then. This may have been partly due to the fact that we arrived on a Thursday and Thursday, as we quickly discovered, is the one day each week when neither alcohol nor meat can be bought or sold.

After a night at the Great Eastern Hotel, we boarded a train at Howrah station, carefully picking our way over the many hundreds of refugees living on the platforms. Indian Railways do not seem to have changed very much and the overnight journey from Howrah to Burowni Junction had little to commend it other than an excellent plate of mutton curry purchased at a wayside station. This event almost caused a young RAMC sergeant who was also on the train to have apoplexy, and he implored us not to eat this succulent dish. He gave us a condensed and well delivered lecture on hygiene in the eastern countries to which, as we ate our curry, we listened politely. He did his duty but I think he was genuinely disappointed not to see us writhing in agony within the hour.

We changed trains at Katihar the following morning and arrived at Jogbani that afternoon. Jogbani is in India and it is some ninety miles from there across the border to Dharan where the headquarters of British Gurkha L of C is situated.

There was no transport to meet us which was a disappointment. We learnt later that this was because it takes longer for a signal to get from Calcutta to Dharan than it does to travel there by rail; the reason for this being that the signal has to travel through diplomatic channels. However, there was a Landrover that had been sent to collect the RAMC sergeant, and we lost no time in letting this person know that he had guests for the journey.

Unfortunately our party of three (Gil Roach is a very large officer) including our not unsubstantial equipment would not all go into the Landrover: not, that is, in addition to the driver, a friend of his who had come for the ride, the friends' children who presumably also came for the ride and of course the RAMC sergeant. After much argument and many cups of tea in the local police station we managed to shed some of our equipment for later collection and everyone squeezed into the vehicle. There was also by now an Australian lieutenant who had muscled in on the act and we managed to get him in too!

Dharan lies in the south-east corner of Nepal where the northern plains of the Indian continent give way to the foothills of the Himalayas. This is fine country and the headquarters there has a good permanent home with many facilities. It is to these barracks that the recruits from the hills of eastern Nepal are first brought.

From Dharan we flew to Kathmandu while Bhimbahadur was sent on to western Nepal in order to attend to his own affairs and also to enlist our porters prior to our arrival in Pokhara. Pokhara was to be the starting point of our trek.

Kathmandu is a fascinating mixture of the very very old and the alarmingly new. It even has its share of street corner boys in tight trousers and with long hair, carrying transistor radios; but few of these find their way into the Brigade.

We stayed for two days in the Panorama Hotel; a very friendly establishment notable for having no views of any kind from any of its windows. We walked and trishawed all over Kathmandu and also visited the ancient town of Patan which dates from AD 299 and is noted for its temples with their guardian deities and endless carvings—many of them erotic in the extreme. Kathmandu is over 4,000 ft high and the climate at this time of year was perfect; warm and sunny during the day and cold enough for blankets at night.

From Kathmandu we flew to Pokhara. The internal and some external airways of Nepal are operated by The Royal Nepal Airline Corporation using mainly the ubiquitous Dakota and generally flown by Nepalese pilots who negotiate this alarming terrain, with its mini-size airstrips tucked away in the corners of great valleys, with panache and considerable skill. No seats or air hostesses in these aircraft; this one had hard benches down each side and most of the space in the centre was occupied by sacks of fertilizer, a variety of tin boxes, thermos flasks and tiffin carriers filled with steaming curries.

There were also several live chickens. We clambered in as best we could. I had an Isreali schoolmaster on one side of me and a Nepalese trader on the other, both of whom had recently been eating extremely well-spiced curry!

During this flight we saw much of the country that we were to walk through, and most impressive it looked with its sharply defined hills soaring up to 10,000 ft and more and its wide river-filled valleys. The rice harvest was almost ripe and the rich splashes of colour showed that almost every hill was cultivated to its summit. We could pick out many villages perched in apparently the most inaccessible places joined together by only narrow footpaths. There are no roads in this part of Nepal and indeed few roads at all in the whole of the country. To the north we could clearly see the Himalayan peaks, huge and majestic in their covering of snow. We picked out Everest with ease and Gil took several excellent photographs of the aircraft's starboard wing—how difficult it is to take good photographs of the Himalayas from an aircraft; or indeed to become a Field Marshall!

We stopped briefly at Pokhara, only to exchange a few passengers and an assortment of merchandise. Some of our new passengers were soldiers returning from their villages to the recruiting centre at Paklihawa. This journey from their homes is normally done on foot, often with their wives and children, and it may take a week or more. Travel by air within Nepal is at their own expense; but air travel is cheap.

Paklihawa is a far flung outpost and consists mostly of a tented camp. It is the recruiting centre for west Nepal and a staging post for soldiers travelling to and from their leave. It is a very hot and isolated place for the two or three British officers who live there, although Delhi, Lucknow and even Calcutta are within reach by air. Here we set about preparing the stores and equipment for our trek and here also, for the first time, we met some pensioners from our own regiment.

Someone had told me before leaving Singapore that travel in Nepal required endless patience; here also the truth of this statement was amply born out when the Dakota which was to take us back to Pokhara failed to arrive at Paklihawa. It failed to arrive for a further two days. It seemed that the only reason for this situation was that the ideas of those who write the airline schedules and those who actually fly the aircraft do from time to time differ. And after all why not? There are 365 days in a year and what is a day or two one way or the other?

With this philosophical thought simmering in the backs of our minds we waited patiently, amidst some sixty-five other hopeful passengers and their mounds of luggage, on the side of the hot and dusty airstrip.

Patience was rewarded and we duly arrived in Pokhara. While Bhimbahadur went to summon the porters Gil and I installed ourselves in the "Sun and Snow" hotel—a small group of corrugated iron huts overlooking the airstrip. We spent a fascinating evening crouched in a tiny room, already severely overcrowded by two beds (without mattresses) but which now housed in addition a mountain of kit plus Bhimbahadur and four prospective porters, the employment of which, in true eastern style, took some considerable time to negotiate. This sort of thing cannot be hurried and the merits and demerits of every concession made, or request refused, has to be carefully considered and everyone must have his say on every point. The process was possibly speeded up by the frequent distribution of cigarettes and a glass of rum all round. The glass of rum all round proved to be a disaster because in the almost total darkness I opened by mistake our only bottle of Scotch. Agreement was finally reached at seven rupees per day per porter with food in addition and a plan was made to start at six the next morning.

Our first days' march was 15 miles down the valley of the Seti river. This was mostly easy going through flat and beautiful country with rice and other crops just beginning to be harvested. This area was well populated and we passed through many villages and met many people working in the fields. All had a cheery word and were interested in where we had come from and where we were going and why. Friends who had been in the army were hurriedly summoned. Brothers and sons in the army were discussed and the merit of the crops was a topic of lively interest. Occasionally we would meet a soldier on his way back to the recruiting depot from his leave and this also entailed a halt, particularly if he happened to be in the Gurkha Engineers. We soon learnt that if we were to get anywhere at all we would have to be selective about those with whom we stopped to talk.

We quickly developed a daily routine which, by no means rigid, normally entailed being on the march by seven o'clock just as the dawn was breaking, the porters having previously brewed up the essential early morning cup of tea. In this way we were able to cover a lot of ground in the coolest part of the day. We ate our morning meal at about half past nine or ten and then walked on until three or four in the afternoon which gave us time to set up camp and cook the evening meal before dark. We were generally turned in and asleep by seven-thirty or eight. This plan had the advantage of fitting in with the Gurkhas' normal routine of two meals per day. It was possible to buy a meal at many of the villages in the valleys and we sometimes did this at our morning halt, but generally it was more convenient to buy rice and vegetables and have it cooked by the porters at some suitable stream in the open countryside. At night too we cooked our own food having pitched our camp not too close to a village as this had the advantage of a certain amount of privacy which was otherwise quite unobtainable. Gurkhas are naturally curious people and one's every move was minutely watched. Every mouthful of food was carefully followed by a host of dark brown eyes all working as one from the plate to the lips, and many a village school suffered from complete absenteeism when we were shaving. Other more intimate details of ones day to day existence are more conveniently carried out in solitude and thus we tended towards the open spaces; but this was no guarantee against the really determined Saheb-watchers, some of whom I suspected of walking many miles in order to satisfy their curiosity.

Our four porters were all delightful fellows and we quickly became a very happy band. Two were Gurungs and two were Kamis and they cheerfully carried their heavy loads—sometimes 60 lb—day in and day out with never a murmur. They collected firewood and they cooked; they heated shaving water and made tea in the dark; they scrubbed the pots and pans and put up tents; they sang and told stories and were hugely happy. I was carried across more than one river on one of their willing backs, but this was a facility not extended to Gil Roach whose large frame we felt might cause a disaster.

We crossed the Madi river in a hollowed out log at Sisaghat Bazar and at the end of the second day we halted two miles short of Kunchha having covered 29 miles. Kunchha was quite a large town at about 3,000 ft and we had a sharp climb up to it early next morning. We were surprised to meet there a bearded American youth who was a member of the Peace Corps and claimed to be an "adviser". We questioned him closely and persistently on what he actually did, but his replies remained evasive. The end of the next day saw us across the Marsyandi river, this time over a fine suspension foot bridge, and we halted in Tarkughat.

So far we had been on one of the main east-west tracks and amongst a constant flow of travellers, but now we were to go off the beaten track northwards to a village called Lakhajung which lay at over 5,000 ft and at which we were to investigate the improvement of the water supply. We bought two days' supply of rice and vegetables and set off early next morning. This was a stiff climb up a little used track and our leg muscles soon began to suffer. Bhimbahadur thought little of this having Gurkha legs, and went bounding away like a mountain goat. He was a hard taskmaster but even so we failed to reach Lakhajung that night and stopped a few miles short of it at a tiny village called Yumri where we spent the night perched on a steep hillside. The inhabitants of Yumri were fascinated by our arrival and said that no European had visited them before, but we suspected that this might not be true. We soon found that one of the young men there had a brother who was a sapper in the regiment and relations were firmly established. One old man was a pensioner from Indian Army days and took it upon himself to be responsible for our welfare. He discharged this task by producing a wooden bottle full of rum. He also brought with him a small boy who was despatched at frequent intervals to have the bottle recharged. The rum made in the hills is called "raksi" and is a raw spirit distilled from rye. This was not a particularly pleasant brew as it had just come out of the still and was rather warm. We slept well.

The next morning was spent carrying out our reconnaissance in Lakhajung. It was an unfortunate day to have chosen for such work because it was the first day of the Dewali Festival during which ancestral deities are worshipped in order to ensure future well being and prosperity. The inhabitants of Lakhajung had their minds firmly set upon gambling, beer and rum and our eager concern for their supply of water was regarded at first as unnecessary and even frivolous. Indeed it was a good hour before any male member of this community could be persuaded to desist from his worship and come and talk to us. However, after we ourselves had done our bit towards the encouragement of ancestors in general we got down to business and spent a profitable few hours doing what we had set out to do.

Our next task was to investigate the possibility of building a footbridge over the Chepe river and the contact man for this was a retired Gurkha officer, honorary Lieutenant Bharti Gurung who lived at the village of Tajib. The maps of Nepal that are available to the British Army are based on a survey carried out in 1924 and it was perhaps not surprising that Tajib is not where the map says it is. Where Tajib should be lies Tashyo, and Tajib is several miles away on a different mountain spur altogether.

The business of seeking directions and distances was fascinating. In general the direction of a particular place was accurately pointed out, but to obtain two diametrically opposed and forcefully expressed opinions on the distance to any place and the time taken to reach it, only two people needed to be asked.

We arrived at the house of Bharti Gurung on our sixth day having covered a total of 70 miles. I have never been a great man for walking and indeed have never walked if any form of transport was available. But now I found myself positively enjoying it; the whole tempo of life in the hills was geared to the pace of walking and I found myself really able to appreciate the delights of the countryside through which we travelled, and perhaps most important, there was absolutely no other form of transport for the eye to see or the mind to dwell upon.

Bharti Gurung's hospitality knew no bounds and we were soon installed on the first floor of the tiny village school house; fires were kindled, tea was brewed and everyone rushed hither and thither while the school-children watched every move with enormous interest. Indeed it was difficult to get in and out of this small apartment as the hole in the floor through which we gained access was permanently jammed with small brown bodies. The Top of the Pops was undoubtedly me blowing up my Lilo which brought out many appreciative "oohs" and "ahs" and a generous round of applause. The women of Bharti's family had prepared a fine meal for us and we sat late, cross-legged upon the verandah of this house in the hills and as the consumption of rice and raksi rose so did the volume of reminiscences. In our appreciation of this hospitality we gave Bharti the last of our bottle of Scotch. Although this was undoubtedly highly prized it was just a little sad to see it poured into a pot already half full of raksi and declared as an excellent cocktail.

We had set aside the next day to do our reconnaissance of a bridge site on the river Chepe and were anxious to make an early start. We agreed with Bharti Gurung, who was coming with us, that we would make a start at eight-thirty. The preliminaries next morning, however, included a large meal of rice and vegetables, preceded by an omelette; the assembly of the complete family for photographs to be taken; and the provision of large quantities of food to be carried with us.

We got under way at eleven o'clock and set off down the steep slope to the valley below where lay the Chepe. Bharti led the way moving, for all his fifty years or more, like a young recruit, and we arrived breathless at the river side. The proposed bridge site was some way upstream and we were led through a steep gorge along ledges no wider than a matchbox at breakneck speed. There were a few cracks in the rocks into which one could just get ones fingernails and 50 ft below the Chepe bore its way at a steady 10 knots or so. There was I am sure a perfectly normal pathway round this obstacle, but Bharti was enjoying himself hugely by putting us through the hoop. This small bit of mountaineering was difficult enough to negotiate carrying only a small haversack, but the porters carrying their heavy and bulky loads were never far behind; how they managed it I do not know.

During our reconnaissance we crossed over to the east bank of the Chepe by the only bridge that exists on this river. This was a very frightening affair of cantilevered bamboos with neither decking nor handrails. This structure was confidently expected to be washed away each year in the rains. The previous year it had lived up to expectations; but it had taken four people with it. Bharti Gurung crossed with us and took us to the house of a friend of his and we were refreshed with draughts of cold home-made beer followed by a dozen or so of those delightful little tangerine oranges. Soon we waved our good-byes to Bharti and were on our way once more up into another line of hills on our way south.

This proved to be our hardest day yet and we were soon faced with a very steep climb. It was exhausting work but the view when we reached the top was superb. On our right, far below us now, lay the Chepe river and many miles away reaching high into the sky was the snow-clad peak of Machhapuchhare—23,000 ft high—and the Annapurna range. Behind us was the 26,000 ft peak of Himalchuli jutting through the clouds into a brilliant blue sky and below us on our left flowed the Darondi river. In front of us the track led away to the south, slipping first to one side of the ridge and then to the other. In the distance lay the ancient hill-top town of Gorkha.

It was difficult to find a suitable place to camp because the ridge was narrow and the villages were all some distance away from the track. It was almost dark when we eventually settled on the outskirts of a small village called Chisopani, and very aptly named too. This was somewhere between 5,000 and 6,000 ft high and was bitterly cold. Our tents were pitched in a very stony and steeply sloping field and I shivered for most of the night even though I was fully dressed in all my reserve clothing and inside my sleeping bag.

This was the night that my Lilo developed a puncture.

Morale was not at its highest the next morning. Petrified figures stumbled about in the darkness trying to brew tea on dew-soaked firewood and hoping to warm themselves in the process. It was a sluggish start; even the spectators gallery was slow in appearing, but a few hardy souls turned up to watch the fun and they sat huddled in their blankets on top of a low stone wall. This somewhat depressing interlude was suddenly ended by the rising sun which within a matter of seconds produced a scene of quite startling beauty. As the first rays of sunlight crept over the ridge behind us they fell, many miles away, on to the snow-capped peaks of Machhapuchhare. They appeared, perfectly outlined in gold, to be suspended in the cloudless blue sky. The valley below us was still in semi-darkness and shrouded in a thick mist. Gradually the sun crept down from the peak and the whole scene was slowly turned into a more earthly panorama. We set off on the days march with a light step.

Our goal that day was Ampipal some eleven miles to the south-west where there was a mission that we wanted to visit. We found a handful of extremely happy people in Ampipal. The head of the mission was an Australian; there were two school teachers, one American and one Austrian; the doctor was a most attractive Canadian lady; there were one or two English and American nurses, and another Canadian and a German who were agriculturists. Theirs was an incredibly small world of paraffin lamps and water from a pump and they lived, many of them with their wives and small children, a very hard-working and simple life. They had nevertheless made themselves comfortable; I saw more than one paraffin refrigerator. Supplies of all sorts, including their mail (and the refrigerators) were carried from Kathmandu on the backs of their own porters. This was a three-day journey each way but during the dry season the air service to Gorkha airstrip, a mere three hours walk away, was often used. They themselves thought nothing of walking to Kathmandu; indeed during the rainy season there was no other way of getting there. This wonderful little band of people ran a hospital; a school of 300 pupils; a teachers' training class and an agricultural station.

Ampipal was a fairy story village sitting right on top of the three peaks of its very own mountain. The highest peak of the three was occupied by the school and the very summit had been sawn off to provide the school playground; and what a playground it made! Our host invited us to attend early morning service in their church before we visited their various departments. This was a very simple service conducted by a Nepalese and was attended by most of the Western staff and a handful of Gurkhas. My impression throughout our time with the mission was that little was being done to try to convert the Gurkha to Christianity and that all effort was put into the fields of education, medicine, and agriculture.

The hospital was really a treatment centre for out-patients and dealt with a great number of these each day, many of whom walked, or were carried for several days in order to get there. One unfortunate young man with a broken back arrived while we were there. He had been carried by his brothers through the hills, slung in a hammock attached to a long bamboo pole. His aged mother had also made the journey. There was one small ward of about ten beds where the really sick could be detained and a small room was set aside for emergency surgery; but necessarily carried out under poor conditions, as there was no electricity.

We arrived at the school to find all the pupils assembled on the playground and were slightly taken aback to hear ourselves being introduced to the assembly at large as "the visitors from the British Army in Malaya". We stood up in order to identify ourselves the better and I felt not quite at my best for this situation, dressed as I was in a somewhat ragged pair of corduroy slacks, a not very clean shirt, and an extremely battered wide brimmed Gurkha hat that was unhappily slightly too large for me. However we were accepted as representatives of the British Raj and those children who had fathers or brothers serving in the Brigade were asked to come and talk to us. About a dozen did so and we went to some trouble to note the names and units of their relations. The interpretation of "brother" in this part of the world is somewhat loose and I was a little put out when, having gone to some trouble to locate these men after my return to Malaya, some of them denied all knowledge of such relationships. My fatherly attempts to be the bearer of long-awaited family tidings fell somewhat flat.

Our visit ended with a tour of the agricultural station and having tea and popcorn with the Canadian family who ran this part of the mission. It was strange having an English tea served up in a china tea service after so many days of drinking our porters' vicious brew out of our mess tins; but it was extremely pleasant.

There was little we could do in a practical way to express our gratitude for the hospitality of these wonderfully kind and charming people. We gave them all we had of the good things they lacked and that we could well do without for the next few days; but this only amounted to a tin of butter, two jars of marmalade and a toilet roll (to replace the mail-order catalogue in vogue at the time).

We left Ampipal that afternoon and set off down into the Marsyandi valley where Gil Roach and I were to go our separate ways; I to return to Kathmandu by air and he to walk with Bhimbahadur by a different route back to Pokhara. We said our farewells in the village of Thantipokhri over the inevitable glass of tea and a rather stale biscuit. I turned south taking two of the porters with me and after an hours hard walk down the river side I reached Gorkha airstrip. Although called Gorkha airstrip, Gorkha town is some nine miles away to the east and some half mile higher. This airstrip is merely a levelled earth runway alongside the river surrounded by a couple of strands of wire. There was a windsock and a small open-sided shelter that housed a very old and weathered weighing machine and that is all. During the summer there are four scheduled stops a week by the service which flies between Kathmandu and Pokhara.

The only sign of life came from a small hut a few yards outside the wire which was obviously the source of tea for intending travellers; this indeed was the only building of any kind in sight. There being nowhere for my porters to feed, and we were now carrying next to no food, I had my tent pitched between the airstrip and the river and despatched the two boys back to Thantipokhri for the night, telling them to return by ten o'clock next morning.

It was a beautiful place to spend a night and I settled down to enjoy thoroughly the majestic scenery and the glorious isolation. I lighted a fire with the wood already collected by the two boys and then set off to the river for a bathe. As I walked through the trees I heard some small animal scamper away from my path; there was nothing unusual in this but it reminded me of a conversation that had taken place in the little hospital at Ampipal about a man who had been brought there badly mauled by a bear. Interested in this I had asked where this attack had taken place and was told that it had been on the other side of the river from Gorkha airstrip. For the remaining 100 yds or so to the waters edge every snapping twig and every rustling leaf was a potential bear and my bathing was quite spoilt by my vivid imagination. Admittedly the bears were supposed to be on the other side of the river, but could bears not swim? I thought they probably could, and might even enjoy doing so. I felt at my most vulnerable when standing naked at the edge of the river, being eyed from behind every tree. I returned to my tent having met only a couple of rather friendly squirrels.

As I brewed my tea and warmed up a tin of sausages in the gathering dusk an old man emerged from the shack on the far side of the airstrip and came towards my tent. After a friendly greeting he settled down on his haunches to pursue the business of finding out all about me. He quizzed me relentlessly for twenty minutes or so and his curiosity was then apparently satisfied. He did not, however, approve of the fact that I had dismissed my porters and was cooking my own supper, and he made this point with some force. I had to some extent offended his image of the travelling sahib.

"Sahib, have you no fresh milk for your tea?" said he, as I punctured my last tin of Nestles.

"No." I replied, and knowing what was coming next I hastily added "I prefer tinned milk to any other kind."

"Ah" he said, attempting to patch up the image a bit "the least I can do is to see that you have fresh milk for your tea."

He bounded away across the airstrip towards his hut and reappeared a few minutes later bearing with him a very dirty glass containing an inch or so of goat's milk—far from fresh and of the consistency of thin porridge. I thanked him profusely for this kindly gift and put the glass on the ground near my well-brewed tea and waited hopefully for him to go. He did not go and I had to drink my tea with the goat's milk in it. He politely refused a proffered cup, but gladly accepted half my tin of Nestles which he bore away in his glass. There was no doubt that I had been taken for ride!

Nevertheless he was a pleasant old chap and he returned later on to sit by my fire and talk. Somewhat foolishly I asked about bears, and of course got in return all I deserved. Bears? Of course there were bears. On this side of the river? Oh yes, all bears are renowned for their swimming. And so on; I was even told of a bear that had killed a bullock on the very spot where my tent was pitched.

Looking back on this conversation there is no doubt that most of what the old man said was nonsense; he was out to impress. And singularly successful he was because I spent a simply wretched and quite sleepless night, with a heavy stick by my side and listening to every tiny sound.

My porters turned up on time next morning, happy and gay after a good nights sleep in Thantipokhri and they soon had everything packed up and installed in one corner of the shelter beside the weighing machine. It was important to me that I flew back to Kathmandu on this particular day as I had a flight to Calcutta already booked for the following day and a Commanding Officer in Singapore confidently anticipating my arrival on the day after that.

Intending passengers soon began to arrive and the usual pile of motley baggage quickly grew to an alarming size. The boy with the broken back was there still suspended from his bamboo pole; there was a very old and immensely fat man who arrived in the Nepalese equivalent of a sedan chair and a whole host of other colourful citizens, most of whom I hoped were spectators.

No aircraft had arrived by midday nor had any official of the airline. This was disconcerting and my few casual inquiries elicited only the fact that the 'plane was due "sometime in the afternoon". I knew better now than to point out that the schedule forecast a midday arrival. In the meantime my old friend of the previous evening did a roaring trade in tea—no doubt with my milk.

At three in the afternoon a young man arrived with a sheaf of blank manifests, some carbon paper and airline tickets, a ball point pen and an empty money bag. This seemed sparse but nevertheless adequate equipment and manpower for the job in hand and I could not help making a mental comparison with other movement agencies I have known. This movementeer had walked the nine miles or so from Gorkha from where he had radio communication with Kathmandu and he was thus armed with the information that the 'plane "might arrive about four o'clock". There seemed to me to be an element of doubt about this forecast and I asked him why this should be. I was told that the pilot who was to bring the 'plane was at present flying a different service from Delhi to Kathmandu, and if this proved to be a tiring journey then . . . and the rest was expressed in a shrug of the shoulders.

My ticket for this flight covered the journey not only from Gorkha to Kathmandu but from Pokhara to Kathmandu and I had particularly bought it in this way in case I had decided to walk back to Pokhara. But the fact that I produced a ticket already paid for cut little ice. What was the use of presenting a ticket at "B" for a journey from "A" to "C"? It was ridiculous, for a few moments it was even hilariously funny, but it was not to be tolerated. The only way of boarding his aircraft was for him to issue a brand new ticket in exchange for hard cash firmly pouched in the money bag. In view of the fifty or sixty intending passengers pressing in from all sides I paid up quickly, fairly confident that I would get a refund for the other ticket in due course.

I never discovered by what method the available seats were allocated although I suspect it had a financial flavour. It certainly had nothing to do with advance booking. My seat I think was secured by Nepalese natural politeness. At five fifteen a sudden outburst of cheering heralded the Dakota now to be seen picking its way through the mountains.

By a quarter past six I was in Kathmandu. The following day I flew to Calcutta and visited the transit camp at Barrackpore where our Gurkha soldiers stage during their journey from Malaya to Nepal.

By the next night I was back in Singapore.

During my month's journey I had learned much about Nepal and her people, particularly the hill farmers of the west from where many Gurkha soldiers come. I had seen something of their homes and their village life, and tasted something of their charming and natural hospitality. I had seen some of the most striking scenery in the world; walked over 100 miles and lost 8 lb in the process.

Nowhere else have I ever met such a likeable and happy people; such a relaxing and satisfying environment.

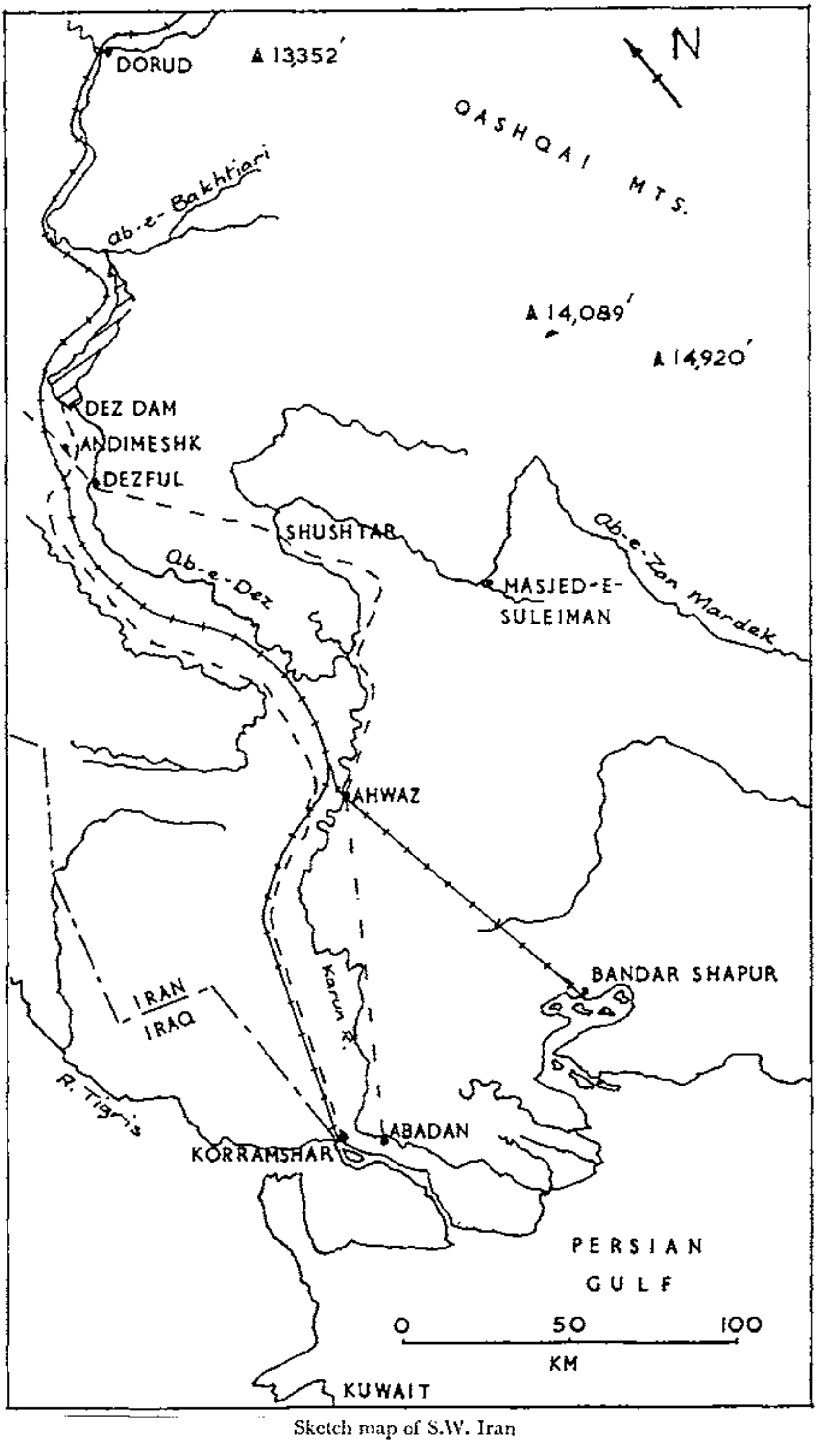
Adventure Training in Iran 1965

By LIEUT B. COX, RE

As many readers will know it is customary for Sapper YOs studying for degrees at RMCS Shrivenham to undertake some form of adventure training during their second year summer leave. Four of us, Lieuts Cox, Stuart, Wyatt, and Travers, at the invitation of an uncle of mine, decided to visit a large irrigation hydroelectric scheme on the R. Dez near Andimeshk in SW Persia. This was an appropriate choice as three of us were studying civil engineering and Lieut Travers was studying electrical engineering. (We still are—just!). Thanks to the kindness of Caravans International we managed to procure a Bluebird caravan conversion of a Commer van, and other firms helped us with free or cut-price food.

Thus it was that the grey dawn of 24 June saw our departure from Shrivenham, laden to the gunwales with 8½ cwt of food, among other things, having proved yet again that a goodly proportion of the adventure in adventure training consists of actually getting started. We were given an official send-off from Westminster Bridge by a bevy of Press reporters and photographers, and a Director of Caravan International's public relations firm, not to mention an eye-catching array of wives and sweethearts. Our route through Europe followed the well beaten track through Belgium, Luxembourg, Bavaria, Austria and Yugoslavia, and apart from one or two energetic moments on the steeper Alpine passes, nothing untoward occurred. In Greece the elation produced by our first glimpse of the Aegean was swiftly tempered by ten hot minutes spent digging the van out of the soft sandy foreshore.

The next country we reached was Turkey, and we now began to feel we were making progress, particularly when we saw the distant hills of the Gallipoli Peninsula to the South. We arrived in Istanbul six days after our departure from London. This was our halfway point, but we knew the worst was to come, and come it did! After crossing the Bosphorus to Asia our route passed through Ankara to the Black Sea coast, then inland again to Erzurum. The latter stretch included some atrocious gravel roads and a pass almost 8,000 ft high. We also encountered several washed-out reinforced concrete bridges; the Turks seem to effect considerable economies by omitting expensive items such as cement from their concrete. The only way of bypassing these was to drive down the bank, across the stream bed, and up the other side.



Sketch map of S.W. Iran

From Erzurum we drove on to the Iranian border post at the foot of the majestic snow-capped cone of Mt Ararat. After this the roads became really rough and through Kurdistan the country became steadily more desolate and arid. Key points on the road were guarded to prevent sabotage by dissident Kurds. After 400 miles of stony corrugated road we were relieved to find that a new tarmac road had been built from Kermanshah to the Persian Gulf. As a result we drove into Andimeshk 16 days and 4,200 miles after leaving London.

Andimeshk is situated on an arm of the vast Tigris—Euphrates plain five miles from Dezful and ninety miles north of Ahwaz. About five miles east of Andimeshk the mountains of Khuzestan rise abruptly from the plain. Through these mountains, which rise in places to over 14,000 ft, the River Dez has cut its way, forming narrow gorges 1,000 ft deep. The Dez Dam has been built across such a gorge some four miles upstream of where it debouches on to the plain.

The Resident Engineer was expecting us and immediately took us in charge, as my uncle was in London on leave. After a single day to unpack, service the van and generally get ourselves sorted out, we found ourselves at work. We spent a morning being briefed and poring over racks of drawings, and were immediately impressed by the magnitude of the whole project. The dam is of double curvature thin arch construction and is 646 ft high. It is 66 ft thick at the bottom, tapering to a mere 14.75 ft at the top, which overhangs the bottom by about 75 ft, a fact which caused a certain amount of trepidation on our first walk across the top. The access road to the dam plaza and transformer platform passes through the longest unlined tunnel in the world (5 km.).

The country rock is a cemented limestone conglomerate nearly as strong as concrete, but in spite of the rock being almost entirely free of joints or faults an extensive grouting curtain has been found necessary and work is still going on.

Very early in our visit we were introduced to the mysteries of grouting and spent many hours up to our ankles in water watching the grouting teams at work in the adits.

Next on the list was a visit to a site for a subsidiary irrigation dam downstream from the main dam. Here we were shown cores being taken and test pits being dug to verify the structure of the rock beneath the site. The irrigation scheme associated with the Dez Dam is at present in the pilot stage, and various crops are being tested to determine their suitability for local soils. Many miles of concrete lined canals have already been built and more are to be built in the future. We accompanied a tour of inspection of these canals, and were shown the effect of scour on some of the familiar 'cementless' concrete placed by a local contractor.

The chief item of interest however was the dam itself. We spent a great deal of time in the company of the Resident Engineer discussing the problems which were encountered during construction. These centred principally round the complete absence of working space on the site before the access tunnel was built. The only route in for material and equipment was originally down the cliff. All the 700,000 cu yds of concrete used came down the cliff by aerial ropeway from silos perched on the top. Another problem was the siting of the power house and turbines. The dam itself will eventually have eight 110,000 hp Francis turbines driving 65,000 kW generators; at present

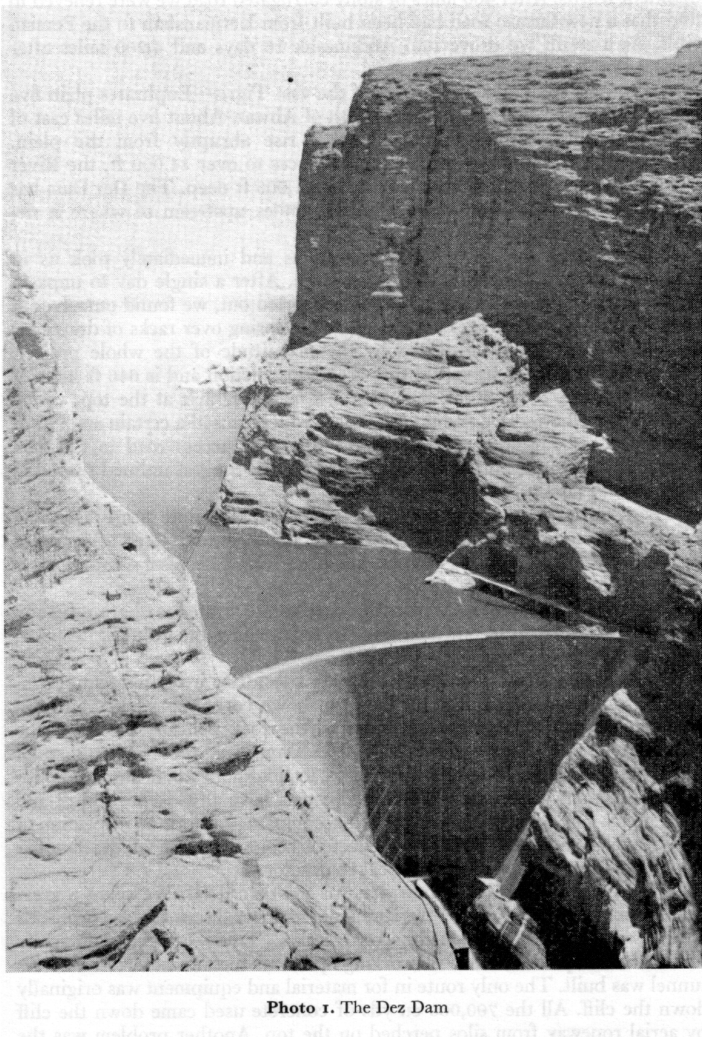


Photo 1. The Dez Dam

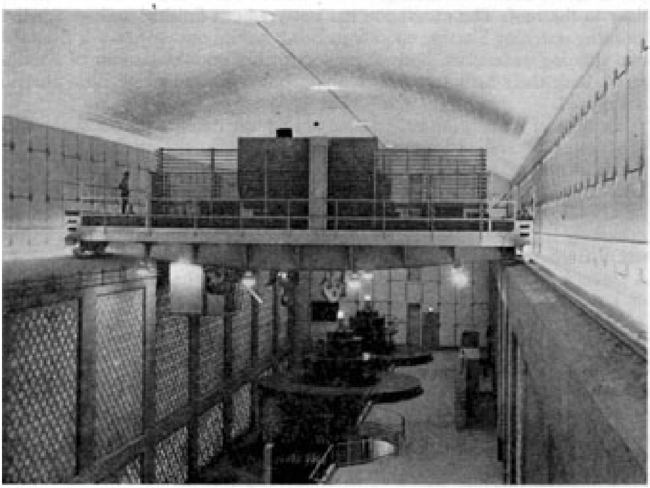


Photo 2. A view of the Powerhouse interior

Photo 3. A common navigational problem!

Aventure Training in 1965   2 & 3

only two are installed. All this equipment is being put in an underground power house about 410 ft long, 60 ft wide and 115 ft high from the turbine floor to the roof. The excavation has not yet been finished and we spent a morning watching blasting operations being carried out only 30 yds from the two running generators, both aligned to within one thousandth of a millimetre with their turbines, with nothing but a flimsy-looking blast curtain interposed.

In spite of a full work programme not all our time was spent at the site. We visited several historic places, including Susa, the ancient capital of Persia mentioned in the Book of Ester, as well as more modern indications of Haft' tapeh. These trips were usually very exhausting because of the extremely high temperatures we encountered. If we stopped the van in the extremely high temperatures we encountered. If we stopped the van in the sun the temperature inside quickly rose to the sixties; that is to say 160°F! A far cooler proposition was a tour of the lake behind the dam which stretches 60 km into the mountains.

We reluctantly left Andimeshk on 25 July and drove back to the frontier by way of the beautiful tiled mosques of Isfahan and the contrasting modernity of Tehran. Our return route through Turkey followed the south coast, and we felt a sense of achievement on seeing the distant mountains of Cyprus, as three years previously we had sweated our way up those same mountains during our Sandhurst Winter Camp. After two years of academic life we could only sigh for the lost fitness of our youth and drive on to Istanbul.

The remainder of our journey home was enjoyable, if uneventful, and we arrived on Westminster Bridge at 10 am on 27 August after driving 10,600 miles over some of the worst and best roads the world has to offer.

Our thanks are due to those firms which helped us, in particular Caravans International, for making possible an unforgettable and highly instructive experience.

New Thinking on Damp Eradication and Water Proofing

By P. E. BURRAS

Technical Director, Damp Eradication Limited

DISFIGUREMENT and decay resulting from dampness in building structures, particularly those designed for human habitation, is an unnecessary evil today.

Down through the centuries decay was relatively unimportant. Replacement was both plentiful and simple. Nowadays architecture has become detailed in the essential and certainly more ambitious in the provision of barriers to overcome the malignant effect of dampness. In containing erosion of building materials by excluding moisture, buildings become warmer and the atmosphere in the living area drier and healthier. Preservation has thus become important, either by design or accident, to our well-being and comfort.

It was not until the turn of the latter half of the nineteenth century that serious thought was given to the inclusion of a damp-proof course in a building and much later when actual legislation made inclusion law.

About this time Victorian architects were pre-occupied with removing servants to quarters in the garret and, at the other end of the scale, sinking basements below the ground level to house the kitchens, stores rooms and wine cellars. Unlike the grandeur and spaciousness of the main rooms between garret and basement, the protection against moisture ingress into the top storey was minimal and waterproofing in basements was almost non-existent partly due, it must be acknowledged, to the lack of knowledge and requisite materials to deal with such problems.

It was a long time hence before water ingress and water-tables were considered with the importance and understanding that is rightly shown today. At least it can be said that the Victorian architect, with great fore-thought, multiplied living area without encroaching on surface land that was, even at that time, valuable by sinking functional rooms into the ground.

To conform to the new legislation requiring living accommodation to be protected from rising damp by the introduction of a barrier at ground level, architects and other responsible persons used various materials. Raw materials readily available, such as slate, were an obvious choice. Much later refinements and by-products of the tar industry came into prominence. The usages came to be known as traditional or conventional. A further method was to build-in a line of extremely hard bricks which resisted moisture.

Effective as these materials proved, limitation of durability was governed by outside factors. Slate, although effective in every way as a barrier, was brittle. The passage of time and water in and through the foundations of buildings caused settlements and unequal stresses; sections of walling dropped and the slate, being brittle, fractured and the dammed moisture rapidly broke through the fracture. Bituminous felts and such-like concoctions, though admittedly not brittle, reached a fatigue stage when the tar constituent was no longer durable and equal to the task, and moisture again allowed to syphon through perforations. The method of utilizing hard bricks was obviously limited by the fact that the mortar joint still allowed moisture to pass through and bridge the line of hard brickwork.

Most buildings of a greater age than twenty-five years (some younger than these) suffer from the foregoing defects and it becomes necessary to reinstate and remedy the breakdown. Obviously, in the case of a building where no damp-proof course exists the insertion of a barrier is essential if habitation requires the maximum of comfort and protection.

In the case of basements, semi-basements and cellars, up to relatively recent times, hardly any have anything like the protection required to check even first degree intrusion of dampness. Certainly no defence whatever to actual moisture ingress.

Such deficiencies are well nigh calamitous in this present day of continuous demand for space and more space suitable for living quarters and dry storage for industry. Millions of cubic feet space are even now available if only modern methods, now employed by the specialist, were called upon. It is surprising that landlords and industrial leaders sit above space that they consider unsuitable for use because of damp and water intrusion when such space could be reclaimed, economically, into dry productive space.

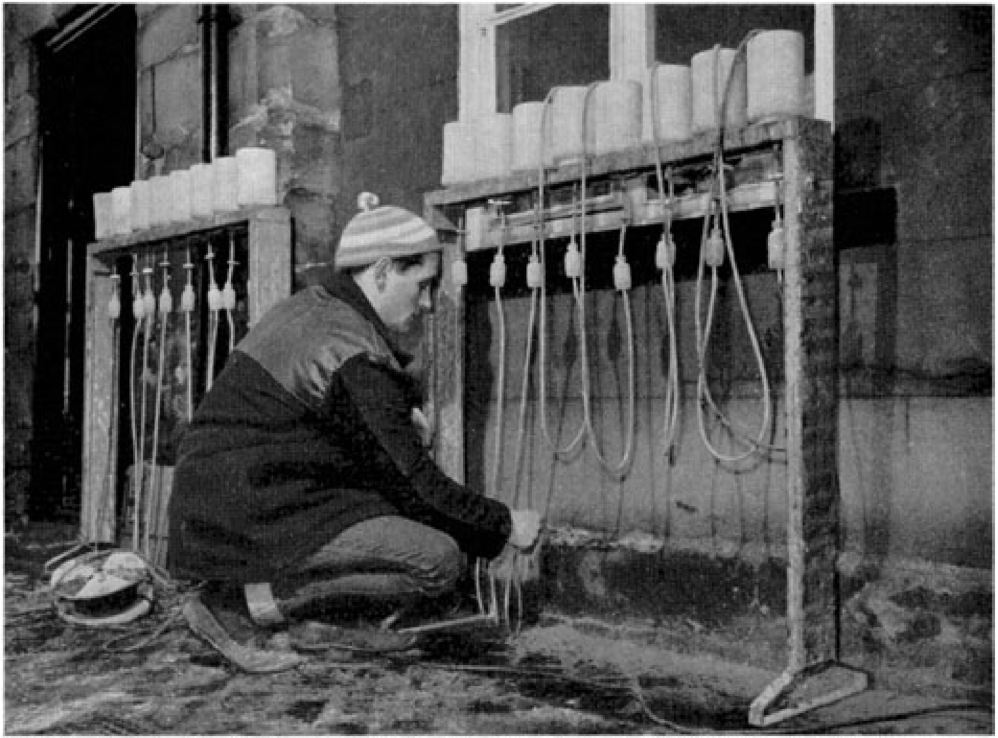
Up to very recent times the remedy for a barrier against rising damp lay in the laborious and costly business of cutting out the brickwork and replacing piece by piece, section by section—theoretically sound, but in practice, apart from the economics, not so. To match and blend the new with the old was akin to inserting a new patch in an old garment—the seam, or abutment, was weak.

In the case of proofing against water, bituminous products gained prominence. The construction of a completely water-tight cellar or basement, in water-logged ground, presented many difficulties. In time, leaks appeared from cracking or shrinking, unequal settlement or increased height of water-table. Most modern underground structures have exterior tanking applied at the time of construction, but even so, through movement by cracking, shrinkage or settlement, the tanking can become fractured or weakened, and moisture finds a way through.

Up to recent times tanking of underground structures has always referred to a skin applied on the outside surface, immediately between the earth and masonry. Tracing leaks and repairs after completion is, therefore, most difficult. To tank (or re-tank) in this manner calls for extensive excavation at an extravagant cost and, it will be appreciated, this is often impossible in built-up or functional areas.

In both water proofing and provision of barriers against rising and penetrating damp new thinking had to be given to the problem. New materials had to be sought; materials that would not disturb and be sufficiently "elastic" to move with the building yet remain stable and actively repellent to moisture. About this time great interest was aroused by the claims of an industry not yet large, but destined to be. Pioneered in Britain, but developed in the United States, silicone resins and siliconate preparations were being produced and found to be more agreeable than claims and tests, then going on, on wax preparations to determine water-repellent efficiency.

This was the new thinking—the alteration of surface tension within the water surface and the angle of contact between the edge of the water and the solid material already *in situ*; the achievement of a means to cause water to globulate instead of spreading; a water-repellent suitable for masonry in



Chemical damp cure transfusion sets are set-up outside a seventeenth-century house in Mill Street, near Warwick Castle, Warwickshire, and tubes from the transfusion sets are being placed into holes that have been drilled in the wall. The picture shows that there is little or no disruption to the exterior of the house when a chemical damp course of this kind is used.

New Thinking on Damp eradication and Water Proofing that it employed large molecular structures and thus low volatility and able to form a stable chemically continuous film.

Likewise, but particularly bearing in mind the water penetration into below-ground structures, research into the modern chemicals to internally treat (which can be seen to be doing its job) against any water seepage, whether under pressure or even tidal, produced materials and development that made it more than capable of eliminating the problem.

Introduction to Chemical Damp Coursing and Water Proofing

Materials were available, but now came the searching problem of how best to introduce:—

(*a*) a preparation of such low viscosity into and through the complete thickness of a wall to give continuity in a horizontal line at damp course level and

(*b*) to prepare basement surfaces to receive multi-coat treatment in such a way as to remain continuous and concurrent to resist cracking and movement.

Devious means were tried but none gave the control essential to success.

In the case of damp coursing, merely to pour the solution into ingress holes without the knowledge of where the solution was going was of no value. Differing degrees of porosity and absorption rate in a given wall gave the more porous section too much to the detriment of the less porous and thus a continuous, linked treatment was either guesswork, improbable and, in most cases, impossible. So the matter rested with the material tried, tested and equal to all the tasks required of it, but the means of efficient introduction and application so far escaping the engenuity of the applied technician.

Recently, however, a team headed by myself and specializing in the eradication of such problems, successfully evolved and assimilated a technique giving, in the case of damp coursing, all that is necessary to control, calculate and introduce correct quantities of solution to a given volume of masonry ensuring linked treatment in both depth and thickness. Thickness of walling, whether brick or stone, solid or varying cavity, random-built or rubble-packed presents no problem to this method. It will conform to all in its adaptability.

Success for this method and the internal treatment against penetrating water has followed fast. Efficacy of the methods and treatment is now acknowledged by leading authorities in Britain and abroad.

Exciting days; research and vast experience gained by a small band, now growing at a fantastic rate, holds the interest and patronage of leading authorities; architects and surveyors of repute are more and more moving towards methods that give satisfaction and an efficient cure for the searching problems of all intrusion of damp and water to affect appearance and structure at an economical figure without the disruption and disturbance that is present when the so-called traditional methods are employed.

The importance of these treatments is acknowledged but more so now when rebuilding and other projects are seriously curtailed by the present national economic crisis. It is now possible for schools, industrial buildings, public institutions, hospitals, barracks and the like, that have been scheduled for rebuilding because their usefulness has been made impossible or inadequate by dampness and ensuing decay, to be given a new lease of life and carry on functionally to an acceptable standard of dry and, therefore, warmer habitation for many years to come.

The economy is relieved and the slant against authorities requiring occupants to live, work and carry out their duties in below standard structures is averted and overcome. It is a duty to give this lease of life now that treatment is economically available. Hundreds of houses, many churches and a cathedral, numerous industrial buildings and places of historic interest and now Brompton Barracks testify to these treatments. Nowhere is it necessary today to put up with damp or water, whether rising or penetrating.

A Common Heritage

By SCAMPERDALE

26 MAY 1966 will mark the 250th anniversary of the day on which the Engineers and the Artillery of the Board of Ordnance went their independent ways. A resumé of the history of these two famous arms up to that date and their common heritage may not, therefore, be out of place in this issue of *The Royal Engineers Journal.*

MYTHOLOGY AND MOTTOES

The Gunners and Sappers both have the same patron—Saint Barbara—who, like her near-contemporary Saint George, was martyred for the Faith during the persecution of Diocletian, a Roman Emperor who strove to eradicate Christianity from his empire with a ruthlessness only matched by a much later Dictator's determination to expunge the Jews from the Fatherland.

The guarded official statements on the lives of Saints have always been adorned by long-cherished legend and flamboyant embellishments. A missal will refer on 23 April, his Feast Day, to Saint George of Coppadocia, as being beheaded for the Faith about the beginning of the fourth century. He was known in the Eastern Church as the "Great Martyr" and this cult spread widely in the West. A church was dedicated to him in Rome and England took him as national patron. Since the days of the early Crusades, however, legend mounted Saint George on a fiery steed slaying a fearsome dragon—he was thus depicted on the gold currency of this country and in many famous works of art. There are similar adornments in the case of Saint Barbara. The same missal for her Feast Day, 4 December, says that she was a virgin of Nicomedia and the victim of her father's anger on account of her faith who shut her up in a tower where she died. Honoured at first in the East, her cult soon became popular in the West also, where many legends about her were venerated. The most generally accepted recounts that she was the daughter of Diosonus, an influential Roman citizen of Nicomedia who, in accordance with the dictates of the time, conformed to the worship of the Roman gods and the virtual godhead in Rome in the person of the Emperor. Whilst away on a distant journey he shut up his young daughter Barbara in a tower where she, who had secretly been converted to Christianity, had three windows made in it in honour of the Blessed Trinity. Discovering her conversion on his return and her refusal to recant her faith, Diosonus was horror-struck.

Terrified of being denounced for harbouring an enemy of the State, he brought Barbara before the Prefect who, according to the scale of punishment then in force for professed Christians, sentenced her to death by mutilation of a quite unprintable nature. Relenting, Diosonus requested that he himself might execute his daughter. The request was granted, and he cut off her head with his sword. Retribution was swift. The skies darkened. The heavens opened. Diosonus was struck dead by a thunderbolt beside the decapitated body of his young daughter.

In early times Barbara was constantly invoked as a protectress against thunder and lightning and against sudden, impenitent death unfortified by the Rites of Holy Church. Devotion to her was introduced into the West, together with that of Saint George, by the early Crusaders. The first use of gun-powder in the fourteenth century in demolitions and in cannons, and the similarity of its explosion to a flash of lightning and a clap of thunder, no doubt led to the adoption of Barbara as the patron saint of all Sappers and Miners and Gunners, both users of this dangerous powder, and all those whose job it was to manufacture, store and supply firearms and explosives. The early Gunners must often have invoked Saint Barbara since the first pieces of ordnance frequently burst on firing, killing the gun crew serving them. Traditional pictures of Saint Barbara show her standing by her tower, which has become the emblem of many military Engineer Corps. The Arms of the Board of Ordnance, who for over four hundred years administered both the Gunners and the Sappers, had as its crest a hand issuing from a mural crown, and grasping a thunderbolt. This device also appeared on the blue ensign flown by RE-manned "ships, vessels and boats"—the old Submarine Mining and Transportation ensign. It is also the crest of the 105 Engineer Regiment (Tyne Electrical Engineers) TA to this day.

The motto of the Board of Ordnance, *Sua Tela Tonanti*, resounded in itself like a peal of thunder, and this same motto was taken by the Royal Military Academy, Woolwich, established in 1741 specifically for "instructing the people of the Military Branch of the Ordnance, both in theory and in practice, whatever might be necessary or useful to form good Officers of Artillery and perfect Engineers". Embryo good Gunner Officers and, more or less, perfect young Sapper Officers continued to graduate from the Shop from then until its closure in 1939. This long history of a common *Alma Mater* in the Board of Ordnance and pre-commissioning co-education at the RMA, Woolwich, apart from the cadets for commissioning into other arms of the services at the Royal Military College Sandhurst, established in 1799, led to a unique special relationship between the Royal Regiment and the Corps.

This relationship was indeed stressed again in 1832 when King William IV granted to both the Royal Regiment of Artillery and to the Corps of Royal Engineers permission to wear on their appointments the Royal Arms and Supporters, together with a gun and the words *Ubique* above the gun and *Quo Fas et Gloria Ducunt* below it. There was nothing strange in the presence of the gun in the Corps badge. Up to and including the Crimean War (1854–6) and the Indian Mutiny (1857–8) the Sappers were responsible for the siting and the construction of batteries into which the Gunners moved their pieces and fired them. In 1868, however, when this Royal Engineer assistance was outdated, the gun was omitted from the Corps badge, but the mottoes *Ubique* and *Quo Fas et Gloria Ducunt*, equally applicable to both Gunners and Sappers, were retained, and many generations of Gunners and

Sappers have served with distinction in every campaign and major engagement and ever followed the path whither right and glory lead.

Both Gunners and Sappers wear the grenade as an adornment. The RE Grenade has nine flames and the RA Grenade but seven. This, however, does not infer that the Sappers are more flamboyant than the Gunners. Indeed we have the reputation of being either "Mad, Married or Methodist", whilst members of the Royal Regiment are said to be "Poor, Pious and Proud".

Development of the Army from Early Days to 1716

Before considering the origin and early history of the Sappers and Gunners prior to the day they went their separate ways, it is necessary to sketch in, as a background, the development of the Army from Saxon times until the partition date of 26 May 1716.

The Saxon Army

The primitive Army of the English—the Fryd—consisted of free landowners between the ages of 16 and 60 who had to turn out when required for the defence of the country and to bring with them certain personal weapons according to the measure of their property. After the conquest of the land by Canute (1016 to 1036) a new military element was introduced by the establishment of a Royal Body Guard of *House Carles*, a force of several thousand permanently-embodied armed men maintained by the King. It was a Saxon army framed on this model of raw levies and the better trained *House Carles* that, flushed from its victory at Stamford Bridge, was decimated on 14 October 1066 by the Norman invaders.

The Army in Norman and Plantagenet Times

After the victory at Hastings, England became an appendage of Normandy, and William introduced into the country knight service and the Continental system of binding up the tenure of land with certain military obligations. Landed noblemen and others had either to produce, on demand, armed forces of a definite size, or alternatively contract out by the payment of money to the Sovereign. It was with these funds that the Norman kings were able to fight their battles with hired mercenaries. Richard I employed mercenaries for his wars and even the knights accompanying him on his Crusade were in his pay.

The early wars of Edward I and Edward II against the Welsh and the Scots were waged by forces raised by this feudal system, and it was the temporarily-impressed English longbowmen in the armies of Edward III, the Black Prince and Henry V who so materially contributed to the victories at Crécy in 1346, Poitiers in 1356 and Agincourt in 1415 during the Hundred Years War against France.

The Wars of the Roses and Tudor England

The Wars of the Roses were fought by armed levies raised by the Yorkist and Lancastrian noblemen and from this long drawn-out civil strife emerged Henry VII, who, like Canute before him, raised in 1485 a permanent Royal Bodyguard. It exists to this day as the Yeoman of the Guard and its members still wear the Tudor uniform, similar to the dress in which their forbears were originally clothed. Military matters progressed but slowly over the next hundred years; there were few overseas commitments and the country relied for her defence primarily upon her "wooden walls". Indeed, the first duty of the land forces was to man the fleet in times of national danger. A volunteer effort, however, emerged in the sixteenth century. The Honourable Artillery Company was founded in 1537, and in 1572 the first English volunteers went to Holland to help the Dutch fight against the Spaniards for their independence. Many English gentlemen served as soldiers of fortune in Continental armies, thereby educating themselves in the art of land warfare, and whole regiments of Englishmen and Scotsmen were raised for service with European countries.

The Great Civil War and the New Model Army

At first both the Royalists and the Parliamentarians raised casual levies and during the first three years of the Great Civil War, 1642–51, a number of inconclusive actions were fought. In 1645, however, the Parliamentarians decided to raise a permanent force, regularly paid, uniformly dressed and equipped and properly trained and disciplined. By this means the New Model Army was formed and within a short time it completely mastered the Royalists. King Charles I was executed in 1649 and, having dealt with opposition in England, Cromwell took his army to subdue Ireland with an iron hand. He then turned against the Royalists in Scotland and on 3 September 1650 with 14,000 of Monk's troops he defeated 27,000 Scottish Royalists at Dunbar. Exactly a year later the last pitched battle of the Civil War was fought at Worcester. Thirty-thousand of the New Model Army, under Cromwell, utterly routed 12,000 Royalists and King Charles II escaped with difficulty with his life.

At the end of the Civil War the New Model Army was 50,000 strong. It was the finest fighting force in Europe and dreaded accordingly. Three of the Dunbar regiments were taken to serve on board ship and in 1652, after a series of desperate naval actions, supremacy at sea in home waters was wrested from the Dutch.

Meanwhile, backed by the rest of the New Model Army, raised only seven years before in support of democratic principles, Cromwell displaced Parliament and proclaimed himself Lord Protector. In need of money he dispatched a force to seize some rich Spanish West Indian islands. As a result Spain welcomed the exiled King Charles II to Spanish Flanders and espoused his cause. Thereupon Cromwell sent 6,000 men of the New Model Army to serve with the French under Marshal Turenne. They were disembarked from ships of the British Fleet and took part in the Battle of Dunkirk Dunes where the Spaniards were totally defeated. One small body of infantry alone stood fast until, surrounded and completely out-numbered, it laid down its arms. They were the loyal Englishmen who had followed their King into exile and made themselves his guards.

The Restoration and the Formation of the Standing Army

On 3 September 1658 Cromwell died. After several months of confusion Monk concentrated his troop in Scotland at Coldstream and, marching to London, restored the Monarchy. In May 1660 King Charles returned and the disbandment of the New Model Army began. This had almost been completed when an insurrection the following year showed the need for an armed force to preserve the peace. Despite Parliament's natural hostility, a Standing Army was authorized on 14 February 1661. It consisted of a Regiment of Horse and two Troops of Life Guards, a Regiment of Foot Guards (the 1st or Grenadier

Guards), raised from the Englishmen who had fought at Dunkirk, the Scots Guards for duty in Scotland and Monk's Regiment of Foot (the Coldstream Guards) alone among the New Model Army units that had not been disbanded. In 1662 a Regiment of Scots in the service of the French, drawn from a Scots brigade that had served under Gustavus Adolphus of Sweden, returned home to become the Royal Scots. In that year the King married the Infanta of Portugal, who brought him Tangier as part of her dowry. To garrison this possession, practically invested by fierce Barbary priates, a Regiment of Dragoons (the Royal Dragoons) and a Regiment of Foot (the Queens) were raised.

The present British Standing Army had come into being and with it our first overseas garrison where fighting never ceased.

Development of the Standing Army 1661–1716

Charles II, as a result of trade rivalry in the East Indies and the west coast of Africa, declared war against the Dutch in 1665. The fighting was mainly at sea where Monk, now the Duke of Albermarle, was to demonstrate that he was as able an Admiral as he had been a General. A strange outcome of the war was that an English regiment in the Dutch service, remote descendants of the volunteers who had gone to fight for the Dutch against their Spanish masters in 1572, returned home to be incorporated into the British Army as The Buffs. In 1679 a detachment of Guards was sent to Virginia to suppress a rebellion—the first instance of the use of the Army as Imperial police. In 1680 a further regiment was raised for duty in Tangier (The King's Own). In 1684, the year before his death, Charles was forced to abandon his wife's wedding present; the Tangier confrontation was absorbing more soldiers than the country could afford. In 1681 a Regiment of Dragoons (the Scots Greys) was formed from independent troops first raised in Scotland in 1675. At the end of his reign Charles possessed a Standing Army composed of some Troops of Life Guards, a Regiment of Horse Guards, two Regiments of Dragoons, three Guards Regiments and four Regiments of Infantry.

The Monmouth rebellion of 1685 against King James II saw the Scots Guards moved from Scotland to London and the raising of six Regiments of Dragoon Guards, two Regiments of Hussars and nine Regiments of Infantry. In addition, two Infantry Regiments, intended for the Dutch service, were incorporated in the Standing Army and in 1688 a further Regiment of Dragoon Guards and two Regiments of Infantry were raised. In the four short but unhappy years of the reign of James II, before his abdication in 1689, the Standing Army had grown apace.

William of Orange was soon at war with varying success against France and, in 1689, the Standing Army was increased by one Regiment of Lancers, one of Dragoons and one of Hussars, and ten Regiments of Infantry. In 1692 another Regiment of Hussars was raised and in 1701 twelve Regiments of Infantry.

It was with this army that Marlborough, under Queen Anne, fought his famous nine campaigns in the Low Countries (1702–11). Gibraltar was captured in 1704 and Minorca in 1708. Operations were also carried out in Spain and Portugal and in Canada.

The Treaty of Utrecht in 1713 brought to a close the War of the Spanish Succession, and the following year George I, the Elector of Hanover, became King. Many regiments were disbanded and the Standing Army was only with the greatest difficulty retained in face of bitter attacks in Parliament. It was the Jacobite Rising of 1715 that in fact preserved the Army's existence, and incidentally, as we shall see, led to the formation of the Royal Regiment of Artillery as a separate entity.

The Standing Army throughout the period covered in this article was in essence only a collection of regiments, each of which was built up on the model of the old mercenary bands. Officers bought their commissions and purchased their promotions and they were virtually shareholders in a commercial venture. Each Commanding Officer was the proprietor of his regiment. All officers received pay but it barely covered the interest on the cost of their commissions. However, all accounting was done regimentally and the commanding officer enjoyed great powers and much independence. The finance branch of the War Office at the end of the eighteenth century consisted of no more than a dozen clerks to check muster rolls and regimental accounts. The men were enlisted for life and, to save the expense of providing replacements, they were generally kept in the ranks for as long as they could stand. They paid, out of stoppages from their pay, for their food, their clothing and for their right to claim a haven in the Royal Hospital, Chelsea, founded by King Charles II for old soldiers. Other than the royal castles there were no barracks in England and soldiers were billeted at a fixed tariff in ale-houses. Like any other labouring man they had to pay for their board and lodging.

Development of the Engineers and the Artillery

The cannon, consisting essentially of the piece, the propellent and the projectile, did not appear on the battlefield before the fourteenth century. The history of the military engineer, however, goes back almost to the dawn of civilization when there was always a demand for men of ingenuity to construct defence works and design, construct and operate engines of war with which to overcome those of the enemy.

Military Engineers Before the Advent of the Gun

We have no record of early English military engineers, but legend indicates that the magician Merlin was employed by King Arthur as his Chief Engineer with considerable supernatural success. The Sappers can, however, trace an unbroken apostolic descent from the Chief Engineer to William the Conqueror. He was Humphrey de Tilleul. He brought with him on the amphibious operation against the Saxons a prefabricated "castellum" of timber palisading to protect the beach-head in case of the need for a hurried re-embarkation.[1] After the victory at Hastings he was ordered by William to remain there as commander of the "Base Sub Area". He was thus debarred from carpet-bagging through the country like other land-hungry Norman knights and, plagued by rumours of his wife's infidelity, he defected back to Normandy. William's next choice as his Chief Engineer was Gundulf, a monk from Bec, well versed in the art of building great abbeys and fortified castles. He is perhaps the father figure of the Corps. His first task was to build the great White Tower of the Tower of London to overawe the Saxon citizens which still stands today with its Chapel of Saint John and its guardian ravens. He later became Bishop of Rochester and started the construction of the present Rochester Cathedral. Gundolf's Tower still stands and the present Cathedral houses many Royal Engineer memorials and each year the RE Memorial Service is held therein. Gundulf was followed by Waldivus

[1] Depicted in the Bayeux Tapestry.

Ingeniator Regis, mentioned in the Doomsday Book, who held nine manors under the Crown in return for his services as Chief Engineer to William the Conqueror and William Rufus. The Pipe Rolls of the Exchequer of the thirty-first year of Henry I, 1131, shows Geoffrey Ingeniator as the Chief Engineer in the King's pay—a not inconsiderable sum in those days of £10 12*s* 9*d* a year for his services to the Crown. He was, however, once placed under stoppages for £2 for poaching a stag in a royal forest. Even in those early days Sapper officers loved hunting.

Allnoth was Ingeniator Regis during the reign of Stephen (1135-54) and during the early part of the reign of Henry II. He received the same basic wage as his predecessor but considerably more in perks. King Richard's military engineers were perhaps the finest in the world of their day. Kyrenia Castle, built by them as a place of safety for his Queen, is well known to all Sapper Officers who have ever served in Cyprus, and they showed that they were equally skilled in assaulting fortified places in the Holy Land. In the reign of King John and the early part of that of Henry III the King's Chief Engineer was Magister Albertus. He was given land in addition to his normal pay and also appeared to be in receipt of a form of marriage allowance and a grant to mount himself on a suitable palfrey. During the middle part of his reign Henry III employed Peter Ingeniator as his Chief Engineer and Superintendent of the manufacture of engines of war. During the later part of the reign one known as "Richard Magister Ingeniatorum", became Chief Engineer. He was, however, to achieve greater fame under Edward I in his wars of 1282 and 1287. Edward realized that the subjugation of the Welsh in their heavily-wooded mountainous country was going to be a "Sappers' War" and his Engineer Train in 1282, commanded by Richard, consisted of over 300 impressed masons and other tradesmen of the "castle building" profession and some 1,000 "fossatores" for road and track building. During the campaign of 1287 an even larger engineer force, supplemented by over 2,000 woodcutters (the first Engineer Forestry Units), was employed. The grim walls of the castles they built still frown down upon us today. Richard's engineers also bridged the Menai Straits and successfully sapped and mined under Welsh castles, although the operation to undermine Drosselan Castle produced heavy casualties due to the collapse of a tunnel below the walls. For his wars against the Scots Edward I employed monks to conduct the working of his engines of war and to restore captured castles into an efficient state of defence. From these monks he selected, in 1300, Brother Robert de Ulmo as his Chief Engineer. He was, however, not known as *Ingeniator Regis* nor *Magister Ingeniatorum* but by a new title *Attilator*, to show that he was not only responsible for Military Works Services, but also for the design, development, storage and distribution of warlike machines such as the Springald, etc (of modern French *Atelier*—meaning a workshop or depot). Some say that the word Artillery is derived from the term Attilator, and it is perhaps now a fitting moment to bring the Gunners into the picture.

The Birth of the British Artillery

The advent of gunpowder in the thirteenth century heralded the passing of the great cumbersome engines of war, and also necessitated a complete revision of the art of constructing fortifications. Roger Bacon first made gunpowder in this country in 1248—the actual discoverer of the explosive powder is not known, but all who have worn a "Shop" tie will be conversant with the composition of gunpowder and the proportion of each ingredient. The earliest record of an English gun is a drawing, dated 1326, of a weapon from which an incendiary arrow was propelled. Guns were used by Edward III at the siege of Calais and at the Battle of Crécy on 26 August 1346 directed by his Chief Engineer John Gruynard. It was, however, the English archers who won the day and the French losses exceeded the total strength of the English force. It was also the skilful placing of the archers by John Gruynard, then the Black Prince's Chief Engineer, that ten years later caused the complete rout of the French at Poitiers (19 September 1356).

The Board of Ordnance

The term "ordnance" first occurred in a letter patent addressed to Nicholas Merbury, dated 22 September 1414. The date marks the first indication of the Office of Ordnance in England and a great landmark in the common heritage of the Gunners and Sappers. The early Masters of Ordnance were Ushers of the Chamber and their office was in Gundolf's Tower of London. Their duties were purely administrative and, with the exception of Merbury, who was Henry V's Chief Engineer at Harfleur and at Agincourt, 25 October 1415, none took the field until over a century later when professional soldiers assumed office. Henry VIII gave the Board corporate existence in 1518 and introduced a Lieutenant as technical adviser to the Master. At that time there was a thriving armaments industry in London, encouraged by the King, carried out by City guilds. In 1598 the establishment of the Board of Ordnance was increased and it took control of this industry. In 1603 the Master became the Master General, and his Lieutenant the Lieutenant-General of the Ordnance. In 1685 the Board became a civil Department of State charged with the provision of all naval and ordnance stores. The Master General functioned in two capacities, both military and civil. In his first capacity he commanded the military element, i.e. the engineers and the gunners, and in his other capacity he administered a supply ministry, a lands agency caring for all Government lands and buildings and a survey department in which engineers were also employed.

The "people of the Military Branch of the Ordnance" did not enjoy the independence and exemption from control enjoyed by their brother officers in the Cavalry and Infantry. Commissions were not purchased. Promotion was by seniority and merit alone and could not be bought. Every halfpenny of public money expended was subject to a most scrutinous audit. The Board was a hard task master, but a fair one. However, it did not make for harmony on active service when there was this division of allegiance to the War Office and the Board of Ordnance. The position was further aggravated in that all transport and supply were matters of contract and, therefore, purely financial and the business of Treasury. For over 200 years from the Restoration of Charles II every British army in the field was subject to three different departments. The Board after a long life of over 400 years was finally abolished in 1855, its death warrant being signed by Lord Palmerston, then Prime Minister, on a half sheet of notepaper. The Gunners and the Sappers then came directly under the orders of the Commander-in-Chief at the War Office. One hundred years later we have achieved a unified Ministry of Defence and we still seek to unify the Navy, Army and Air Force.

But we have considerably overrun the span of history covered in this article, and it is necessary to retrace our steps to the days of Bluff King Hal.

Gunners and Sappers in Tudor Times

Very little is known of the Gunners and the Sappers during the Wars of the Roses except for William Pawne who began his military engineering career during the reign of Edward IV. He served as an engineer under Henry VII who formed the first permanent force of artillery and established a Master Gunner and twelve paid Gunners at the Tower of London. Master Gunners were also installed in other Royal castles where, in addition to their care of the castle's guns, they trained local men to serve them should the occasion arise. Pawne became the Chief Engineer to Henry VIII and he served as Master Trenchmaster in Henry's campaign against France at the siege of Terouenne. He also served in the campaign against the Scots and at the Battle of Flodden on 9 September 1513 he captured the Scottish artillery, the Master Gunner of England having opened fire and slain the Master Gunner of Scotland. He returned to France two years later to supervise the fortification of Tourney.

The most outstanding and colourful of the Chief Engineers of Tudor times was, however, Sir Richard Lee. He started his military career as a page and served Henry VIII as his Chief Engineer from 1540. He was also Chief Engineer during the reign of Edward VI (1547–53). Being a Protestant, he was denied office during the five years of Mary Tudor's reign, 1553–8, but he was reinstated to become the Chief Engineer to Queen Elizabeth I. A moments' thought on those tempestuous times will bring to mind the thousand and one important engineer tasks he must have been called upon to execute in France, Scotland and England. Upnor Castle, which he started to build in 1560, stands today as a memorial to him well known to all Sapper Officers. Being a staunch Protestant, he benefited considerably from the dissolution of the religious houses under Henry VIII. He was given the suppressed nunnery of Sopwell in Hertfordshire by his King as a mark of gratitude for his services on which he built a handsome house which he called Lee's Place. Sir Walter Scott in "Woodstock" describes Sir Richard as a sacrilegious old man who brewed ale in the font which he had looted from the ancient Palace of Holyrood while the Church and buildings were in flames. But for all that he was a great Sapper, and no worse and no better than any other in high place under the Tudor monarchs.

In 1575 Sir Richard Lee died and he was succeeded as Chief Engineer by Sir William Pelham. He had served as Chief Trenchmaster at the siege of Leith. In 1562 he had acted as Chief Engineer at the siege and capture of Caen and the following year he had been Chief Engineer at the gallant but unsuccessful defence of Havres and remained a hostage until the terms of the capitulation were fulfilled. Whilst Chief Engineer to Queen Elizabeth he was engaged in the construction of seaward defences and the fortification of the Thames Estuary, selecting Queenborough as a place highly suitable for a naval depot. In 1579 he served in the campaign in Ireland to suppress the Earl of Desmond's rebellion. A period of the Queen's displeasure followed but in 1586 he joined Leicester's expeditionary force to the Low Countries as his Chief Engineer. He was wounded at the siege of Doesburg and died at Flushing on 24 November 1587.

It is not known who held the post of Queen Elizabeth's Chief Engineer during the time of the Spanish Armada (1588); the next recorded Chief Engineer was John van Cranveldt who assumed office in 1603 when the first

Stuart King, James I, ascended the throne of England. He built a castle in Guernsey which was named after him. He was succeeded by Bernard Johnson who was killed at the landing in the Isle de Rhé in 1627. John Lanyon, John Paperill and Cornelius Dribel followed in quick succession as Chief Engineer to Charles I. Sir Godfrey Lloyd became Chief Engineer in 1640, two years before the outbreak of the Great Civil War.

The Great Civil War

There are serious gaps in the records of this eventful period and it is not easy to trace the names of all who took part in the struggle on either side.

Thomas Rudd is mentioned as a Chief Engineer on the Royalist side. John Lanyon and John Papperill also appear to have returned from retirement to serve their King in less senior engineer appointments and to have suffered sequestration of their property and imprisonment as a result. Sir Bernard de Gomme served as an engineer at Marston Moor, Newbury and Naseby and at the siege of Bristol. John Mansell and Samuel Molineux also served as engineers in Bristol and in Ireland respectively. Sir Godfrey Lloyd does not appear to have seen active service in England, although he was proscribed as a conspirator by Parliament. His brother Sir Charles Lloyd saw action at Brentford and was Quarter Master General of the King's Army in Cornwall in 1644. He was eventually compelled to surrender the town of Devizes to Cromwell.

On the Parliamentary side John Lyon was the first engineer given a warrant under Parliament. He was attached to Essex's Army and served as an engineer throughout the War. A Major Morgan was Chief Engineer at the siege of Lathon House. Peter Manteau van Dalem was styled Engineer-General and Eval Tercene Chief Engineer. The most outstanding personality on the Parliamentary side was, however, Nathaniel Nye. He was Chief Engineer and Master Gunner of Fairfax's army. He was considered one of the best mathematicians of the day and he published his *Art of Gunnery* in 1648.

The Train raised to support the New Model Army contained one Engineer (John Lyon), six Assistant Engineers, three Captains of Pioneers, three Lieutenants of Pioneers and a Battery Master. Cromwell's engineers were most proficient and they carried out some most remarkable river-crossing operations. The Parliamentarian gunners were no less efficient, but often their fire appears to have been directed in a spirit of vandalism against non-military targets.

The Restoration

When Charles II was restored to the throne in 1660 the old, totally inadequately small fixed establishment for military persons of the Board of Ordnance was revived. This limitation operated with extreme hardship on the numerous gallant engineers who had fought for the Royalist cause and suffered for their loyalty. Sir Charles Lloyd was selected as Chief Engineer, de Gomme was granted a pension and Lanyon was given a post in the Admiralty where he rose to a high position. Other engineer officers were temporarily employed for special projects.

Sir Charles Lloyd did not long survive in the position of Chief Engineer. He died in 1661 and he was succeeded by Sir Bernard de Gomme, who held this appointment for twenty-two years. He did much to improve and expand the engineer branch and he sent young engineer cadets to study the art of fortifications and siege warfare on the Continent. He was succeeded in 1683 by Colonel Sir Martin Beckman, who had seen active service in Tangier (1661–2). He remained as Chief Engineer to James II and also served in the same capacity under William and Mary. He commanded the Train during William's campaign against the French in Flanders when he had under him, as Second Engineer, Holcroft Blood, who was later to achieve fame commanding the artillery at Blenheim and Ramilies. He also took part in many sea expeditions. He died in June 1702.

War of the Spanish Succession

Queen Anne did not nominate a replacement for Sir Martin Beckman when she came to the throne in 1702 and the appointment remained vacant until Brigadier-General Michael Richards was made Chief Engineer in 1711, the year of Marlborough's last campaign in the Low Countries, and two years before the Peace of Utrecht. Richards had served in Flanders (1692–5), in a sea expedition in 1695, in Flanders again from 1704 to 1706, in Portugal in 1707 and in Spain in 1708.

The absence of a Chief Engineer, however, did not mean that the engineers did not live up to their motto of *Ubique* throughout the eleven years of war in Austria, the Low Countries, Spain, Portugal, Gibraltar, Minorca, in Canada and on the high seas. The Gunners too were equally ubiquitous and the siege trains of Artillery and Engineers employed during the war assumed an unprecedented size. As an example, Marlborough's siege train used in 1708 in the capture of Lille, the most powerful fortress in France, consisted of 100 guns, sixty mortars of varying calibres up to 12-inch, over 3,000 wagons requiring 15,000 horses, the whole taking up a road space of fifteen miles.

The Great Divide

The Peace of Utrecht in 1713 after eleven long years of war brought about the disbandment of many Cavalry and Infantry regiments and most of the Trains. Engineers and Gunners had to be kept at Gibraltar, Minorca, New York and Newfoundland, and a slightly-augmented pre-war establishment of Engineers and Gunners of the Board of Ordnance was authorized and an establishment for Ireland. There was also a half-pay list.

The Artillery officers were discontented at the comparatively subordinate position in which they found themselves and Engineer officers, who had served throughout the war but were not included in the new establishments, were clamouring to be placed there. Those fortunate ones on the establishment were displeased with the low salary authorized.

Brigadier-General Michael Richards was fully alive to these problems. He proposed a scheme for increasing the effective establishment of Engineers and Gunners without extra cost to the taxpayer by disposing of out-dated appointments under the Board of Ordnance, and he strongly supported a recommendation for a Regimental Establishment for the Artillery whereby the Stores of Artillery and Fortifications might be "cheaper and better looked after". It was an attractive proposition, but he was not to see its acceptance whilst he remained in office. He retired in 1714 and Major-General John Armstrong became Chief Engineer to the new King George I. Armstrong had seen service at Cadiz in 1702 and served with distinction in Flanders from 1704 to 1711.

Chief Engineers from Norman Times Until 26 May 1716

King's/Queen's Chief Engineers

Humphrey de Tilleul	1066
Gundolphus	1078
Waldivus, Ingeniator	1086
Geoffrey, Ingeniator	1131
Allnoth, Ingeniator	1158
Magister Albertus, Ingeniator	1200
Peter, Ingeniator	1226
Richard, Magister Ingeniatorum	1287
Brother Robert de Ulmo, Attilator	1300
John Gruynard	1354
Nicholas Merbury	1414
William Pawne	1509
Sir Richard Lee, Kt	1540
Sir William Pelham, Kt	1575
John van Cranveldt	1603
Bernard Johnson	1620
Captain Thomas Rudd	1627
John Lanyon	1627
Lieut-Colonel John Paperill	1628
Cornelius Drebel	1630
Sir Godfrey Lloyd, Kt	1640

Parliament's Chief Engineers

John Lyon	1642
Major Morgan	1643
Peter Manteau van Dalem	1647
Eval Tercene	1654
Nathanial Nye	1657

Chief Engineers of England

Sir Charles Lloyd, Kt	1660
Sir Bernard de Gomme, Kt	1661
Colonel Sir Martin Beckman, Kt	1683
Vacant, 1702–11	

Chief Engineers of Great Britain

Brigadier-General Michael Richards	1711
Major-General John Armstrong	1714

The Jacobite rising of 1715 saw the country almost completely unprepared militarily. The Board of Ordnance could hardly produce a single serviceable cannon for use against the Pretender's men. Richard's arguments had been driven home with a vengeance. On 26 May 1716 a warrant was signed placing the Artillery on a separate establishment of two companies and the establishment for Engineers was increased. The first two Companies of Artillery were formed at Woolwich, and on 1 April 1722 they were grouped with the independent Trains of Artillery at Gibraltar and Minorca to form the Royal Regiment of Artillery. Albert Borgard was the Regiment's first Colonel.

The separation had come about.

Albert Borgard, the first Colonel of the Royal Regiment of Artillery, perhaps epitomized the close relationship between the Gunners and the Sappers. He was a Dane, and after considerable experience in Continental armies he became a Captain in a British train in 1695. In 1699 he was held on the establishment as an Engineer. In 1702 he became a major of Artillery and in 1706 a Colonel of Artillery. After the Treaty of Utrecht, to retain him in the British Army, he was held on the New Establishment of the Board of Ordnance as an Engineer with a salary of £100 a year, plus travelling expenses. He was a most remarkable man. He served in Flanders from 1692 to 1695, at Cadiz in 1702, in Spain and Portugal from 1705 to 1710 and at Vigo in 1719. He was wounded many times, left for dead once on the battlefield and taken prisoner; he lost an arm at the siege of Valencia in 1705. By the time he died at Woolwich, the home of the Gunners, in 1751 he had eighteen battles and twenty-four sieges to his credit. He was in theory and in practice the greatest artillerist of his day and no mean military engineer.

On 26 May of this year we shall congratulate most heartily the Royal Regiment of Artillery on their 250th anniversary, and, while they look back with justifiable pride on Albert Borgard and their first recorded gun of 1326, let us remember Humphrey de Tilleul and 14 October 1066.

The Council of Engineering Institutions

By BRIGADIER J. R. G. FINCH, OBE, BA

THE modern development of engineering society can be said to have started in 1771 when John Smeaton, who built, among other things, the first Eddystone Lighthouse, agreed with others to form the Society of Civil Engineers. The title was chosen to provide a distinction from the Military Engineer. This society, which included James Watt in its membership as well as many other distinguished engineers, continued until Smeaton's death in 1792 and was reformed a year later with a limited membership of fifty to continue to this day as the Smeatonian Society.

In 1818 the Institution of Civil Engineers was formed with Telford as its first President. As the next half century went by and the scope of engineering grew, other Institutions began to form, the Institution of Mechanical Engineers under George Stephenson in 1847, the Gas Engineers in 1863, the Royal Aeronautical Society in 1866, the Electrical Engineers in 1871 and so on. The most recent of these Chartered Institutions were the Electronic and Radio Engineers founded in 1925, incorporated by Royal Charter in 1961 and the Institution of Production Engineers founded in 1921, chartered in 1964.

The first object of these bodies was to provide a meeting place for discussion and an interchange of ideas. It was soon found they also provided an organized approach to the advancement of knowledge; it was the inability of existing Institutions to give specialized attention to new and developing subjects that caused, in turn, new Institutions to be created. Towards the end of the last century the Institutions began to realize that they needed to look more closely into the training, both academic and practical, of their members, and they began to examine candidates for membership in both respects, thereby becoming qualifying bodies as well as learned societies. At the same time, academic education in both science and engineering was spreading in Universities and Technical Colleges, so that candidates with appropriate degrees or diplomas were given exemption from the Institutions' academic examinations. Today a wide range of such courses provides an entry into the profession, whilst the emphasis placed on practical experience and technical responsibility as a qualification, is a feature which is not so apparent in most other countries.

During this period Institutions were developing very much along their own lines with little reference to each other. After the 1914–18 War an attempt was made to draw them closer together through some central body, but this was abortive although the next thirty years saw the growth of many links. The desirability of unifying the profession became increasingly obvious until in 1962 there resulted the formation of what is now the Council of Engineering Institutions. This is a federation able to express a common viewpoint for the first time and which has established common standards of competence for entry into the profession.

There is only one class of member Institution, but otherwise affiliation is open to a wide variety of professional bodies provided they exclude trade-union-type activities. The requirements for membership are that activities conform with the objects stated in the Charter and that, as a qualifying body for professional engineers, the general standards of the Council are met. For affiliation, the former only is relevant. It is hoped that affiliation can help several types of Society and in particular those interested in cross-discipline subjects. In the general organization of the profession in this country there is no clear-cut boundary between science and engineering or the technologist and technician. Some Societies are regionally based and/or functional in character.

The organization of the Council, its Board and Committees follows a normal pattern; and on them all Institutions enjoy equal status and representation, irrespective of size. However, financial support is based on numbers of qualified members. Outside London, the Council functions through Local Committees which co-ordinate branch activities of Institutions. Similarly, some Institutions have branches overseas and others are in process of developing them. Where appropriate, CEI Overseas Committees may be formed on local initiative.

On an international level, the CEI together with the Engineers Guild Limited represents the UK in FEANI, which is a federation of the national bodies of seventeen countries of western Europe, representing 650,000 professional engineers, of which the UK accounts for one third. An important aspect of FEANI are its efforts towards a European Register of Engineers, of significance to this country whether or not it joins the Common Market.

Associated with the granting of a Charter to the Council in 1965 was the Institution of the title of Chartered Engineer. This may be accorded to those who have the requisite qualifications for entry in the Council's register. All Constituent Members listed by the Member Institutions on Charter Day, as professional engineers, can claim use of the title. In order to qualify in future any candidate must have reached the academic standard of a British University degree either by passing the CEI examination due to come into being in 1967/8 or by obtaining an acceptable exemption to this examination through a course in engineering or some related subject. He must also have undergone a period of training and obtained experience of technical responsibility, usually of an aggregate of five years, to the satisfaction of the Institution of his choice. Whilst in the past, Institutions have accepted applicants with Higher National Certificates with endorsements, this is likely to cease and those offering Higher National Diplomas may be required to sit the second part of the Council's examinations. In the above the Council is reflecting the changes brought about by the various Education Acts since 1944 and the present policy trends of the Department of Education and Science, who, incidentally, will provide an assessor on the Council's examinations board.

Apart from the matter of qualification, there is a wide range of problems in which the Council is becoming increasingly involved as a focus for the profession and as a contact with government. A few examples can be quoted, but the possibilities for action range well beyond what the present Council staff can sustain or the subscriptions of members of Institutions may be able to support.

There is a great lack of information about the profession. To some extent the Committee on Manpower Planning under the Department of Education and Science is looking into this field but an ambitious survey carried out through the Institutions and financed by the Ministry of Technology is now in hand. It is hoped that this may throw some light both on the employment of qualified men and how this is related to academic achievement. The whole should reflect on the often-mentioned subject of the engineer's status.

Not unconnected with status is the short fall in recruitment from schools. Here the Council is co-operating with the Royal Society with whom it held a conference of Headmasters at Cambridge last March; with the Schools' Council with whom there was a joint discussion on the "Page" Report on "Engineering Among the Schools" which was widely publicized by the periodical *Engineering*; with the Department of Education and Science through its Interdepartmental Publicity Working Party; with the Confederation of British Industry which is concerned with a different aspect of the same problem. The Council hopes that through its Local Committees better contacts with schools will be achieved; certainly, visits by engineers in conjunction with a Government-financed Mobile Exhibition of Technology have been showing good results. Recently, Universities have reported some upturn in the numbers and quality of applicants for engineering and associated science courses.

The third of many examples that might be quoted is an interest, jointly with the CBI, in the working of the Industrial Training Act which is concerned with the training of technologists and technicians as well as craftsmen. The concept of the Act is a simple one of extracting a levy from industry and refunding firms according to the effectiveness of their training schemes. Unfortunately, industry is organized on a functional basis whereas training needs to be based, in the main, on crafts and disciplines. For the smaller firms co-operative training schemes present their difficulties towards which the engineering profession, as representing the trainee, must address its help. The Local Committees should be able to provide realistic information on how the scheme is shaping in industry itself and unbiased suggestions as to modification of the Act or to improvement of the Act's operation.

Milton once described a complete and generous education as that which fits a man to perform justly, skilfully and magnanimously all the offices, both private and public, of peace and war. To cater, in this space age for the education of such a paragon presents a formidable problem. But for the Chartered Engineer, who, in applying the advances of science towards the benefit of society, is ultimately dealing with people, the need for such an education is evident enough. Specialists and specialization there must be. But along with this must go the wider outlook and the opportunism to apply sound training and experience in many sections and levels of society.

The meaning of the title of Chartered Engineer still has to become significant with the general public. This is not a matter of writing to *The Times*, or a reason for preoccupation with status. In time something may come from the actions of Institutions or the Council and rather more from the new feeling of unity in the profession or aspiration after new standards. In the main, it must come from the work of individual engineers and a wider interest, on their part, in the inter-relating problems of national interest and the nature of progress in the profession.

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The Editor,
RE Journal

11 January 1966.

MINES AT MESSINES

Dear Sir,

Brigadier J. A. C. Pennycuick, in his commentary in the December 1965 issue of the *RE Journal* on Hill 60 and the Mines at Messines, has pointed out that the craters produced by large high explosive mines are apparently comparable in size with those produced by nuclear explosions of very much greater yield. This does not in fact normally happen, nuclear explosives producing craters with linear dimensions of only perhaps 10 per cent less than those produced by conventional high explosives. Perhaps I can explain the apparent disparity in this particular case.

The figures I quoted in my article in the June 1965 *Journal* of a one kiloton device producing a crater 300 ft in diameter and 80 ft deep, was an average figure for heavy density materials and hard rock. The Messines mines were in clay, and charges produce very much larger craters in that material than they do in rock. Even so it is quite difficult to see how craters of the dimensions given could have resulted. Craters of the shape apparently produced by the Ontario Farm mine are just not possible from a single charge unless that charge is spread over a considerable area. I think that the chamber holding the explosive in this particular mine must in fact have been a tunnel running quite some distance and with a small cross section. I also think that the crater caused was probably much more of a ditch and the 200 ft diameter talked about was the greatest diameter of a very oblong shape. The Hill 60 mine produced a much more logical crater. If one assesses the craters that could be produced in three different types of clay by the size of charge buried at 100 ft, the experimental data would indicate craters 32, 39 or 64 ft deep by 114, 128 or 200 ft in diameter. The depth of the crater falls within this range but the diameter is greater than is apparently possible. I think again this is because of the explosive having been put into two separate chambers which could not result in anything but an oval shaped crater. I also rather think that the true depth of the crater is probably less than that quoted since it will undoubtedly have been measured with a plumb line suspended from a stretched tape and would include the height of the lip.

Because of the scaling law which applies, a nuclear charge of one kiloton would in fact have produced craters the linear dimensions of which would be 2.7 times those produced by 70,000 lb of high explosive.

Yours faithfully,

D. R. Whitaker.

Note by Editor:

The figures quoted in the article were taken from the official publication "Work of the RE in the European War 1914–19—Military Mining", derived from measurements made as soon as possible after the detonations of the mines. The full details were:—

Mine Details	*Hill 60 B*	*Ontario Farm*
Depth of charge	100′	103′
Charge	70,000 lb ammonal	60,000 lb ammonal
Crater dimensions:—		
Diameter at ground level	260′	200′
Width of rim	60′	10′
Depth below ground level	51′	practically nil
Height of rim	17′	4′
Diameter of complete obliteration	380′	220′

The Hill 60 B mine was fairly close to the A mine of 53,000 lb explosive buried 90 ft deep. The Ontario Farm mine was relatively remote from any of the other eighteen mines fired.

In both cases the chambers at the head of the long galleries, containing 60,000 and 70,000 lb of ammonal in tins respectively, were, to quote the book, as big as large living rooms.

Some of the craters of the Messines battle still exist today.

The Spanbroekmolen (Lone Tree) crater is a 40 ft deep circular lake. Visitors are challenged to throw a stone from bank to bank but, despite the encroachment of weeds, nobody can. The crater was bought by Lord Wakefield and presented to Toc H as a war memorial. It was named the Pool of Peace.

Lieut-Colonel Sir Tannatt W. Edgeworth David, KBE, CMG, DSO, DSc, FRS, one time Professor of Geology at Sydney University and discoverer of much of the mineral wealth of Australia, who raised the Headquarter Wing of Specialists of the Australian Mining Battalion and was later geological adviser to the Inspector of Mines used to tell the following story. After Lille had been re-entered he managed to locate a French Professor of Geology, M. Barrois, who told him that twelve German geologists had used his laboratory during the occupation, and that on the morning after the explosion of the Messines mines they were marched in front of a German General who "rocketed" them for their advice that the German mines could never be undermined. As a punishment those under forty years old were sent to front-line units and those over forty back to Berlin in disgrace.

Brigadier M. L. Crosthwait, MBE,
Deputy Director of Personal Services (Army),
Ministry of Defence,
London W1.

The Editor,
RE Journal

9 February 1966.

1965 COOPERS HILL WAR MEMORIAL PRIZE ESSAY

Dear Sir,

I have two reasons for writing this letter. First, I have thought for some years that it is a pity that so little use is made of the correspondence columns of the *Journal*, particularly perhaps compared to the similar publications of other Corps. Indeed, I understand the *Journal* itself tends to lack for articles on topical and controversial subjects. However, the lack of articles is perhaps more understandable than the dearth of letters.

Second, and apart from feeling that the *Journal* could advantageously have more correspondents, I would like to comment on the 1965 Coopers Hill Prize Essay, published in your December 1965 issue.

In my opinion, the author has confined his remarks too much to the quantitative need for tradesmen, and did not sufficiently stress the importance of quality. As often as not, the value of one or two really useful tradesmen (Class I if you are lucky, but I am thinking of good Class II), backed by willing and sensible handymen, is just as great, if not more so, than quantities of unpractised allegedly Class III men.

Too frequently nowadays a good tradesman is also a good Corporal or Lance/Corporal Section Commander (or even a Troop Sergeant). These latter, on a trades task, can be required to be both supervisor and to work. This is inefficient. It seems to me the Corps should be much more ruthless in seeing to it that more men are trained up to Class II standard, even at the expense, in workshop and instructor time, of so-called Class III training. The latter is necessary to redeem recruiting promises, but perhaps we should not even pretend that this basic trade training is more than to handyman standard, and the time spent on it should be in proportion.

If this argument is conceded, then there could be very much more flexibility between BAOR and Strategic Reserve Units. This will be because the number of those who are really necessary for trades work, the Class II men, may not be great and anyway, those concerned being of greater intelligence, can be switched from BAOR to "Hearts and Minds" work with greater facility. The essential characteristic of the remainder is that they should be self-disciplined and willing, characteristics which, even without the minimum basic trade training each man will in fact have, any good unit, be it in BAOR or elsewhere, can soon absorb into the rest of the team.

In considering the difficulty of practising men in their trades, it could be that we have thought too much in terms of Squadron—or Troop—tasks. These can be difficult to find, and in the event can too often lead merely to the under-employment of too many semi-skilled men. The problem perhaps comes into better perspective if it is thought of in terms of a smaller task, in which a properly tailored task force, however small, works against a strict dead-line to produce good quality work.

It is also worth remembering that the present Records policy of warning individuals of given trades and standards, that they may be required from BAOR Squadrons at short notice to boost the Strategic Reserve Units, also provides flexibility with BAOR. It is only a short step from this to earmarking trade teams within, say, a BAOR Regiment, which can be used on given types of task. It is fair to assume that the team concept, with the team only being formed when needed, will grow in importance. It is only for the more unusual skills, such as required for well-boring and petroleum installations, that there is the need to have teams permanently available as sub-units.

Yours faithfully,

M. L. Crosthwait.

Colonel GB Pears MC

Memoirs

COLONEL GUY BARNETT PEARS, MC

GUY BARNETT PEARS, born on 5 November 1881, was the son of Sir Edwin Pears, a distinguished advocate at the Constantinople bar. Pears started his search for knowledge at St Paul's School, Hammersmith and maintained it all his life so that as the years passed he became a man of rare erudition. Commissioned from the Shop in 1900 he went from the SME to Sierra Leone and got experience of West Africa which he did not further pursue. From 1905 to 1911 he served at Chatham, mostly with the Depot Battalion and later at Eastbourne as Adjutant RE of the Home Counties Division, TA. It was at Chatham that the writer of this memoir first met Pears, whom we dubbed the "YO's friend" because, unlike most of the posted officers, he frequently came over to our fireplace in the ante-room to pass the time of day. The HQ Mess of that period housed a distinctly dynamic society, enlivened *inter alia* by Macintosh of the Egyptian Army, who introduced us to the winged collar in mess dress and to the two step (La Matchicha) at the piano. John O'Hara More played rugby in the scrum with a monocle screwed miraculously into his face and ate a whole liqueur glass on really important guest nights. Lloyd-Owen, small and stout, had a purple face and a repertoire of astonishing songs to match it. "Passing through the Gauge" was formidable and so were the mounted cockfighting and high cock-a-lorum. We ran a Rugby XV which held its own with first class London clubs every Saturday in the season, not to mention the annual combat with the RNC Greenwich in the Kent Cup. Sankey rowed at stroke and Pears at bow in an RE eight which competed with distinction at Henley and lesser regattas. Sankey and Pears were also founder members of the "Brompton Barrack's Herring Hounds" which, in 1909, became the now famous RE Beagles.

In 1912 and now married, Pears went to Cairo as the Captain of 2 Field Company RE. The Cairo of that era was in the last days of the glittering opera bouffe splendour, which only British officers, British officials and the very rich could afford to enjoy and which the outbreak of World War 1 was soon to banish for ever. Reared in the Levant and an interpreter in Turkish, Pears could both relish to the full the picturesque absurdities of the Egyptian scene and, more seriously, also explore Palestine and Syria, which were then under Turkish rule. On the outbreak of the war, however, every British soldier that could be spared at that juncture from Egypt, was required for the struggle in France, so 2 Field Company soon turned its back on the exclusive grandeurs of the Nile and left for Winchester to join the 8th Division with which it landed at Havre on 6 November 1914. A few days later the Division was in the line about Estaire's all set for the battle of Neuve-Chappelle in the following March. Surviving that costly battle, Pears was severely wounded on 15 April 1915 and was out of action until becoming a Chief Instructor at the Shop over a year later, still lame from his wound but decorated with a Military Cross.

In January 1917 he became CRE 26 Division in Macedonia and took part in the abortive operations about Lake Woiran in the spring of that year and also in the successful break-through in the same area in September 1918. This latter involved Pears and his three companies in prodigies of road-making through several hundred miles of difficult country in order to get his division to Rustchut on the Danube by Armistice Day on 11 November. Three mentions in despatches and a brevet of lieut-colonel were the reward for his services in the Balkans.

By now higher authority had become aware of his extensive knowledge of south-east Europe and the Levant. For the next six years, therefore, with a break in 1920 as CRE North Palestine, he found himself on various Allied Councils and Commissions in Constantinople, Bulgaria and Greece.

In 1924 he returned home to be SO to the CE Eastern Command and in 1925 became CRE 1 Division at Aldershot. His distinguished services to his country, alas, did not save him in 1929 from the monstrous imposition of eighteen months on half pay, a dire experience which afflicted most of us in turn at that period of Army history. In 1931, however, he was again in full career in the MGO's Branch of the War Office and in October 1933 took post as CE Northern Command after which he retired in 1937.

In York he became fascinated with hunting, first with the Rufford and switching secondly to the Cottismore when he went to live in Rutland. For the remainder of his long life one or two "dear horses" lived in his stables tended by a faithful ex-Gunner groom and when he gave up hunting at over 80 years of age, his favourite mare went on grazing in the paddock beyond the garden to the day of his death. At Empingham he entertained a wide circle of friends, especially at dinner and bridge where anybody, who led from a king, learned in the hard way not to do so again. His mordant wit on many topics, his quizzical cast of face and his powers of mimicry, especially of Levantines, made him a most amusing companion. Of Roman coins of a particular period he had a valuable collection and his study of the obscure intricacies of numbers was distinctly a reserved occupation for wranglers. Seemingly tortured by silent doubts about the Christian faith, he investigated its history with the consuming zeal of an ardent theologian. Significantly in this connexion, his beloved brother was a devout Roman priest of great learning; the two of them met seldom, but were constantly in touch by the exchange of letters at which, for his part, Pears certainly excelled.

He married in 1908 the beautiful second daughter of Lieut-Colonel W. T. McLeod then of Dover and is survived by a daughter and a grandson, both of whom live in Rhodesia and are intimately involved in the fate of that tempestuous country. His last years were plagued with illnesses, which he shrugged off in the grand manner and he died quite suddenly on Sunday 21 November, aged 84 and was duly buried at St Peter's Church, Empingham a week later. . . . To have known him was a great experience. RIP.

B.T.W.

COLONEL W. GARFORTH, DSO, MC

COLONEL W. GARFORTH, who was Secretary of the Royal Engineers Benevolent Fund, from 1944 to 1956 died on 11 December 1965, aged 83 years.

William Garforth was born on 20 July 1882, the son of F. Garforth, Esq, of Klinkenberg, South Africa. At the Royal Military Academy, Woolwich, he was awarded the Queen's Gold Medal for proficiency in military subjects and was commissioned, second in his batch of twenty, into the Royal Engineers in July 1901.

After his Young Officer training at Chatham he was posted to India where he served for five years as Garrison Engineer successively at Meerut, Lansdowne, Roorkee and Cawnpore. In 1908 he became Assistant Engineer in the Public Works Department at Dharmsab, and three years later he became Officiating Executive Engineer of the Kangara Provincial District. From that appointment he was selected to officiate as Under Secretary to the Public Works Department of the Punjab. He was on home leave when war broke out in 1914.

Joining the 69 Field Company, raised at Chatham in September 1914, he helped in its training and accompanied the unit when it was posted to France in June the following year and he served on the Western Front for the rest of the war. From October 1916 until January 1918 he was a GSO2 in the Headquarters of the New Zealand Corps and later in the Headquarters IX Corps during the Battle of Lys. He finished the war as CRE 46 Division. He was wounded twice; he was awarded the MC in 1916 and the DSO in 1918 and he was mentioned in despatches four times. After the Armistice he became CRE of a Defence Sector in France before returning to India towards the end of 1919.

For the greater period of his second tour of duty in India from 1919 to 1924 he was Under Secretary of the Punjab Public Works Department.

He spent the final nine years of his military career at home. After a short posting to Bordon he was appointed Staff Officer to the Chief Engineer, Northern Command at York, and, having completed a course at the Senior Officers' School, he became CRE London District in 1926. Whilst in that appointment he was elected a Member of the Committee of Management of the Royal Engineers Benevolent Fund, and he remained a most active Member of the Committee until he became Secretary of the Fund in 1944, after his retirement. He held the position of Secretary until the end of 1956.

His last military appointment was Deputy Chief Engineer, Eastern Command, a post he held from 1932 to 1935.

At the 1956 Annual General Meeting of the Corps General Sir Kenneth Crawford, then Chairman of the Royal Engineers Benevolent Fund, said that it was with great regret that he had to report the forthcoming retirement of Colonel Garforth at the end of the year after twelve years as Secretary. He had been an ideal Secretary. He knew everybody, and he knew every organization that could help persons in need of assistance. He was a most kind-hearted and sympathetic man, but also very tough with scallywags and quick to spot imposters. He had served the Benevolent Fund splendidly and his devotion to the Corps was unlimited. Lieut-General Sir Lionel Bond, speaking as County Secretary of the Soldiers', Sailors' and Airmens' Families Association, endorsed General Crawford's tribute to Colonel Garforth and said that his SSAFA Divisional Secretaries constantly reported what a joy it was to deal with the Secretary of the Royal Engineers Benevolent Fund who was always so kind, sympathetic, co-operative and, when necessary, generous with help.

Garforth married in 1908 Edith Winifred, eldest daughter of Lieut-Colonel C. Herbert, Resident of Jaipur State. She died in November 1963. He is survived by a son Major W. S. H. Garforth who served in the Royal Artillery. As stated earlier in this Memoir William Garforth died on 11 December 1965, aged 83 years. At his special request there were to be no flowers at his funeral, but donations, if desired, should be sent to the Royal Engineers Benevolent Fund which he had served for so long with such dedication and devotion.

LIEUT-COLONEL R. D. GWYTHER, CBE, MC, MSc, MICE

Engineer and Railway Staff (TA)

Reginald Duncan Gwyther, the doyen of the Engineer and Railway Staff Corps, died on 26 November 1965 aged 78 years.

He was educated at Ripon School and Manchester University where he graduated with First Class Honours Degree and continued in residence to obtain his MSc. He represented the University at Rugby Football during the seasons 1906–7 and 1907–8, and he also played in the University lacrosse team against both Oxford and Cambridge in 1907 and in 1908.

After coming down from the University he went to the Argentine as an Assistant Engineer on the construction of the Western Railway tunnel under the city to the docks.

During the First World War he served in the Royal Engineers in France and Belgium, commanding 148 Army Troops Company, RE. He was awarded the MC in 1917 and he was mentioned in despatches.

After the war Gwyther was concerned in a number of important engineering projects at home and overseas, which included the Grimsby Fish Dock, the Johore Causeway, Malaya, the Singapore West Wharf Extension and the Dry Dock, the development of the port of Colombo, and harbour works in East and West Africa. In 1936 he became a partner in the London firm of Consulting Engineers, Coode and Partners, and eventually became the Senior Partner.

During the Second World War he was closely connected with the Mulberry Harbour project and was in 1945 awarded the USA Medal of Freedom (Silver Palm). He was a Member of the Panel of Civil Engineers under the Reservoirs (Safety Provisions) Act and a Member of the Departmental Committee on Flooding 1953–4. In 1954 he was created CBE. He became an Associate Member of the Institution of Civil Engineers in 1913 and a Member in 1928. He was awarded the Institution of Civil Engineers Telford Premium in 1910, 1929 and 1959. He was a Past President of the British Section of the Societé des Ingenieurs Civils de France.

In 1921 he married Dorothy Wilberforce Gwyther. They had two sons. His widow and sons survive him.

LIEUT-COLONEL W. M. N. MORECOMBE, OBE

With the death of William Morris Nicholl Morecombe on 1 December 1965, the Corps lost one of its most renowned electrical and mechanical engineering instructors.

He was born on 17 February 1880 and at the age of fourteen enlisted into the Corps as a Boy to be trained as an electrician. At that time the submarine mining activities of the Corps were at their peak and the use of searchlights for coast defences was becoming a major responsibility. With a flair for mathematics and a natural bent for the practical application of electricity he learned quickly and, after joining the ranks at the age of eighteen soon qualified as a Military Mechanist (Electrical) with the rank of Staff Sergeant. In this specialist appointment he served in a number of the stations of the Corps abroad, including Hong Kong and Malta, and progressed rapidly to the rank of Warrant Officer Class I. On his return to the UK in 1910 he served at Portsmouth and later at Chatham until 1914. At the age of 33, whilst serving at Chatham, he sucessfully passed the examinations of the University of London to become a BSc—an academic triumph for a self-taught student after many years of diligent study.

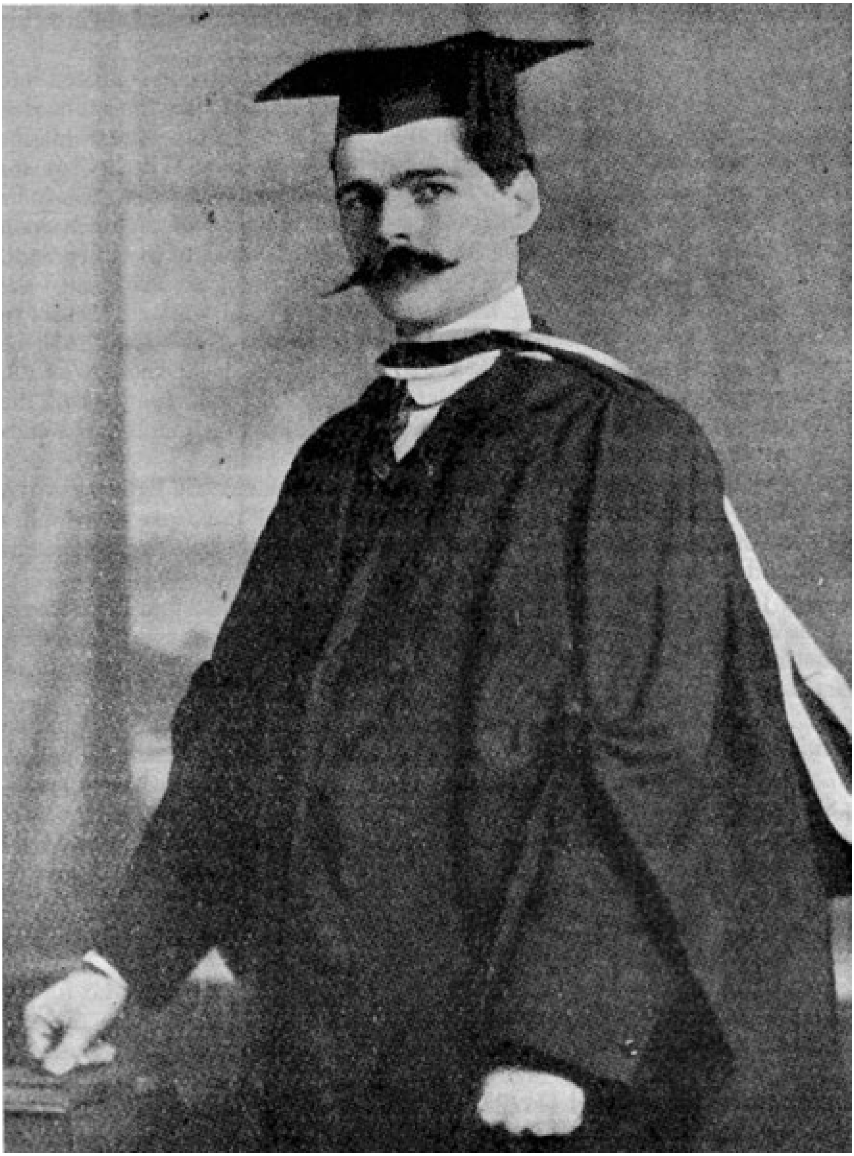
During the 1914–18 War he was in charge of the electric lighting of the installations at Le Havre, the principal base of the BEF in France for supplies and ordnance, with its docks, stores, hangers, hospital, eight reinforcement camps and remount depots.

On 1 July 1918 he obtained a Temporary Commission as a 2nd Lieutenant, but on 2 August 1919 he received his Regular Commission as a Lieutenant (Coast Battalion) within an establishment of the Corps that was reserved for officers particularly experienced in defence electric light duties.

In 1920 he was appointed Assistant Instructor at the School of Electric Lighting, Gosport, and served in that capacity until 1923. At that time the SEL was a training centre for defence electric light duties and the associated trades. In the early twenties the Corps was rapidly adapting new E and M technological development for field use and Morecombe was posted to Chatham, as an Assistant Instructor, to help extend the range of the academic and practical instruction given to students of E and M Courses. Thus began his long association with the SME, and the E & M School in particular, that was to last for some twenty years.

Foreseeing the tremendous expansion of E and M work that the future held for the Corps he concentrated all his energies to ensure that the Military Mechanist (E & M) students could tackle anything that came their way. In so doing he produced a long line of WOs and NCOs who were ready and qualified to serve as E and M officers when the Corps expanded to meet the needs of the Second World War. Students of these pre-war Mechanist Courses were expected to be dedicated to their studies and Morecombe made it quite plain that those who missed instructional periods due to sports injuries could expect to be returned to Regimental duty. He also made it clear that students could not marry and remain diligent at their studies. Once on a Mechanist Course they remained single until they qualified.

After his retirement in 1935 he was employed at the SME in a civilian capacity working for the "B" Committee of the RE Board on the trial and development of E & M field equipment; but on 18 February 1938 he was



Lieut-Colonel W M N Morecombe OBE

appointed Assistant Instructor RE Workshops and continued in that role, in uniform, after the outbreak of war in 1939. The Trades Training Wing, SME remained at Chatham throughout the Second World War and instruction continued in spite of air-raids. In September 1945 he was appointed Chief Instructor to the Wing and served until his second and final retirement from the Corps in June 1946.

Recognition of his work came in July 1932 when he was made a Brevet Major, and again in 1935 when he was awarded the OBE in the July Birthday Honours' List. His technical ability was widely acknowledged by civil authorities and he became a MIMechE and MIEE. In 1929 his textbook "Overhead Power Lines" was published, and in 1931 his "Textbook of Electrical Engineering" Vol X, became the basic electrical engineering primer for military students.

The urge to teach remained with him after his retirement from the Corps and in 1948 he became a part-time lecturer in electrical engineering at the Medway Technical College, Gillingham, Kent. (Now the Medway College of Technology at Horsted, Chatham.) Surely a considerable achievement for a man approaching 70 years of age.

In 1951 he moved with his family to Macclesfield in Cheshire, and later lived at Wimslow, before settling in Hatfield, Herts, where his widow, Mrs May Morecombe, now resides at 29 Brookmans Avenue, Brookmans Park.

"Bill" Morecombe was a brilliant electrical and mechanical engineer who was blessed with an infinite capacity for painstaking effort. His work for the Corps between 1924 and 1935 will long be remembered by those who knew and appreciated his endeavours to keep the E and M work of the Corps to the high standard he achieved.

F.T.S.

Book Reviews

BRIGADIER FREDERICK KISCH
SOLDIER AND ZIONIST

By Norman Bentwich and Michael Kisch

(Published by Vallentine, Mitchell & Co. Price 25*s*)

This biography of Brigadier F. H. Kisch, CB, CBE, DSO, Croix de Guerre, Legion of Honour, the first Chief Engineer of the Eighth Army, killed on active service in April 1943 has been written jointly by Norman Bentwich, who was Attorney General in the British Mandatory Government of Palestine at the time when Kisch was Head of the Jewish Agency, and by Michael Kisch the Brigadier's younger son.

Kisch was considered at the time the best Chief Engineer any Commander could want to have, and his name will be remembered in connexion with the longest advance in British military history. His engineering enterprise had much to do with the conquering of North Africa. His major achievements were, perhaps, his success in piping life-giving water from the Nile over hundreds of miles of barren desert to the far Libyan frontier, and his pioneer work in the art of minefield clearance. It was indeed an ironic tragedy that he, so versed in mine warfare, should himself have been killed by a German mine when going forward to organize repair work at the main road bridge over the Wadi Akarit when the Eighth Army was almost in sight of its goal.

The younger son of H. M. Kisch, CSI, he was educated at Clifton and the RMA, Woolwich and commissioned into the Corps in August 1907. After leaving the SME, he was posted to India and during the First World War he fought most gallantly on the Western Front and in Mesopotamia with the Bombay Sappers and Miners of the Lahore Division. He was wounded on two occasions. Whilst convalescing after his second wound he served in the Military Intelligence Directorate of the War Office and later he served on the War Office Delegation throughout the Versailles Peace Conference, and at its close remained on the Military Staff attached to the Council of Ambassadors.

At his own request he retired from the Army in 1922 and accepted an invitation from Dr Weizmann to join the Zionist Organization in Jerusalem. He became Chairman of the Executive of the Jewish Agency and was associated with the inception of the Palestine Electric Corporation and Palestine Potash Ltd, both of which developed into engineering concerns of high magnitude. From 1932 until 1938 he was in private practice as a Consulting Engineer in Palestine and Director of the Palestine Road Construction Company. He is appropriately referred to in the biography as "The Engineer of the Jewish National Home".

On the outbreak of war in 1939 he was recalled for service as CRE Alexandra, he was promoted Colonel shortly afterwards and became Deputy Chief Engineer, British Troops in Egypt. In February 1941 he became a Brigadier and successively held the appointments of Chief Engineer Cyrenaica, Chief Engineer Western Desert Force and Chief Engineer Eighth Army.

He was a very gallant engineer officer and he gave his best in the service of his country. This excellent and most authentic biography should help to keep alive the memory of his work and example.

THE ORDNANCE SURVEY ANNUAL REPORT, 1964–5

(Published by HMSO)

This Report again gives a concise and readable account of the year's work of the Ordnance Survey.

It details the steady progress being made towards completing the post-war 1/1250, 1/2500 and six-inch resurvey of the country, and gives some interesting information on the methods being employed. For example, the use of helicopters is now standard practice for the six-inch resurvey of the Highlands, a great advance on William Roy's first survey in 1746.

For those interested in Geodesy, the Report tells of further work on the strengthening of the Primary Triangulation network, experiments in satellite triangulation made in co-operation with the Royal Radar Establishment, and gravity observations along the geodetic levelling lines made in co-operation with the Geological Survey and Museum. The Survey also assisted the French Institut Geógraphique National in devizing a method of fixing the positions of trial bore holes in the English Channel for the Channel Tunnel Study Group.

The Research and Experiment section of the Report again reveals the Ordnance Survey's awareness of, and close concern with, developments in aerial surveying, cartography in all its aspects and printing. Indeed the Survey is playing a leading role in a number of fields.

The new maps of which the Report speaks, and the further development of the policy of regularly publishing new editions of the standard series, should ensure that the Survey continues to beat its own sales records.

Officers who have served with the Ordnance Survey will be particularly interested to see that the building of its new home is going ahead. The Survey hopes to move into its fine new buildings in 1967–8, and to be once again firmly based at Southampton. C.W.F.

CHEMISTRY AND TECHNOLOGY OF EXPLOSIVES—VOLUME 2

By T. Urbański, Department of Technology, Politechnika, Warsaw

Authorized translation by Wladyslaw Ornaf *and* Sylvia Laverton

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price £6)

The principle purpose of the book is to provide information of both a theoretical and a practical nature on the subject of the chemistry and technology of explosives.

The contents of this volume include chapters on nitric esters in general, nitroglycerine, other glycerine esters, glycol esters, alcohol esters, nitrocellulose, sugar nitrates, salts of nitric acid, and salts of oxy-acids of chlorine.

Nitrocellulose in particular is very fully covered and a feature of the book is the attention paid both to the properties of the substances discussed and to their manufacture, with the inclusion of details of a number of original processes used in the German and Japanese explosives industries during World War II. Following each chapter is an exceptionally comprehensive literature section and, for example, the chapter dealing with the characteristics of nitrocellulose is supported by a list of 146 separate references. An author index is provided in addition to a subject index.

The book will be most valuable to those wishing to make a detailed study of the chemical properties and the production of explosives. B.S.B.

TEXTBOOK OF TOPOGRAPHICAL SURVEYING, 4TH EDITION

(Published by HMSO, 1965. Price 35*s*)

At the beginning of this century the appearance of a new edition of the *Textbook of Topographical Surveying* was a fairly common occurrence, in that over a period of 20 years, within the span of a Royal Engineer Officer's career, three editions were published. For the present generation the publication of a new edition of the *Textbook* satisfies a long-awaited need. The first three editions were edited by Colonel Sir Charles Close and were published in 1905, 1913 and 1925. Planning for the new edition envisaged a simple revision of earlier editions whilst retaining the same form. The rapid development of equipment and techniques in recent years has however precluded a new edition on the same lines. In place of the earlier textbooks, which were in essence a collection of edited papers based on the experience of Sapper Officers in peace and war, we now have one written by a single author.

The textbook is of about the same length as the 3rd edition. Chapters follow the same general pattern but include some notable changes. The author has recognized the recent publication of *The Textbook of Field Astronomy* and *The Star Atlas for Land Surveyors* in his omission of a chapter on Field Astronomy. He has devoted four chapters to Air Photography and Air Survey compared with quite minimal treatment formally. A new chapter entitled "Reduction and Adjustment of Observations" has been added, a most important improvement. Other new material appears in the form of short chapters on "Map Compilation" and "Revision".

The Tables and Appendices have been pruned, re-arranged and improved. The difficulty with Appendices in a work of this kind is to decide what to leave out. It might have been better to omit "The Cassini Projection—The Hotine Correction" in Appendix E and to bring Appendix H "Scribing" into the relevant chapters. The author discusses different versions of the metre in Appendix G, and might have added a mention of the internationally accepted value as defined by the orange radiation of Krypton-86. The number of worked examples is sensibly reduced to avoid duplication with those in "Survey Computions" and the "Textbook of Field Astronomy".

In reviewing any work of this nature it is only too easy for the reviewer to wish upon the author a degree of foresight which will match developments which take place in a number of specialized fields between the date of completion of the draft and publication. Their omission does not however detract from the value of this textbook provided the reader appreciates that whilst the principles of topographical surveying (which are described most concisely and convincingly) hold good at all times, equipment is being improved whilst techniques become more polished and sophisticated. Unless the reader approaches the book in this way he will look in vain for a detailed exposition of the use of the tellurometer in traversing, or for more information on the transverse mercator projection and the UTM projection and grid, so important today, in the relatively short chapter on map projections. Suffice to say therefore that having regard to the range of the subjects incorporated Major-General Cheetham has succeeded in producing a book which is compact, portable, cheap and capable of being revised with little difficulty. Its high quality printing, pleasing type face, clear diagrams and half-tone reproductions will be appreciated by readers. His real achievement has been to provide a new pattern for a traditional textbook which is essentially for the use of surveyors who have completed a comprehensive course in land surveying and mapping, for example that offered by the School of Military Survey, and which can now provide the basis for successive editions to match the rapid advances in equipment development and techniques. P.C.S.

ADVANCES IN AUTOMOBILE ENGINEERING—PART THREE

Edited by G. H. TIDBURY, Advanced School of Automobile Engineering, Cranfield

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 63*s*)

This book, Volume 7 of the Cranfield International Symposium Series, presents the proceedings of a symposium held at the Advanced School of Automobile Engineering, Cranfield, in July 1964. It contains eight professional papers presented for study and discussion to the 134 representatives of British and foreign research and development establishments, Universities, automobile and production engineering concerns.

The papers summarize the research and development work that has recently been carried out on the theory and eradication of noise and vibration problems in automobiles, with the object of improving ride comfort and fault-proof vehicle construction.

Most of the theories and testing systems presented are technically advanced and only suitable for study by automobile designers and production engineers, but other mechanical engineers would find plenty of interest in the tests carried out on the Pavé Test Track of the Motor Industry Research Association, and the trend of present day thought on ride comfort. Engineering statisticians will be particularly interested in the random process theories for vibration analysis.

As usual, the standard of printing and the style of the book is first-class. F.T.S.

A TEXTBOOK OF MAGNETOHYDRODYNAMICS

By J. A. Shercliff, PhD, MA, Professor of Engineering Science, University of Warwick, Coventry

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 21*s*)

Magnetohydrodynamics (MHD), sometimes designated *hydromagnetics*, is the science of the motion of electrically conducting fluids under magnetic fields.

Whilst generally regarded as a modern subject, MHD stems from the findings of Faraday in 1830, when it was realized that an e.m.f. could be set up in a solid or fluid material when it was moved in a magnetic field, and that electric currents would result if the material was electrically conducting and a current path was provided: also that currents could be induced by changes of magnetic field with time. The consequences of these phenomena, the perturbation of original magnetic fields and motions, provide the base effects of MHD.

Although the science was at first virtually neglected, some application progress was made. Water was pumped electro-magnetically in 1832, and an MHD generator using ionized gas as an armature was proposed by a Mr Peterson in 1919. In 1942 the engineer-astrophysicist Alfvén published a paper on MHD which expressed the finding that if a highly conducting fluid moves in a magnetic field, the induced currents will tend, in some respects, to inhibit relative motion of the fluid and field so that the field is "convected" by the fluid. Subsequent progress was fast.

The theory was applied to cosmic and astrophysical problems, and practically applied after World War II for the pumping of liquid metal coolants in nuclear reactors. Electromagnetic pumping, stirring and levitation (to avoid contamination) were also introduced into the metallurgical industries.

The birth of modern rocketry and space flight offered yet another avenue of use for MHD applications, and at present experiments continue into the realm of energy conversion, storage, and aerodynamics.

The text, which outlines the principles of MHD, is only suitable for advanced undergraduates and postgraduate students. It assumes that the reader is acquainted with vector notation and has some knowledge of fluid dynamics and electromagnetism. Full explanations of these subjects are not given.

A feature of the book is the emphasis laid on *vorticity* and the importance of the rotationality of the magnetic body force.

A chapter is devoted to *magnetogasdynamics*—the theory of compressible flow of conducting fluids.

Problems are set at each chapter end for student practice. F.T.S.

ENGINEER DRAWING AND CONSTRUCTION—VOLUME I

By L. C. Mott

(Published by Oxford University Press, Amen House, London, EC4. Price 25*s* in the UK)

The aim of the author, a practising design-draughtsman and part-time lecturer in Engineering Drawing at Farnborough Technical College, is to present to students those principles of plane and solid geometry, and machine drawing, covered by the syllabi of the General Engineering Course and the first two years of the Mechanical Engineering Technician's Course. His second volume, not reviewed here, is more advanced and designed to satisfy the needs of students taking the revised Ordinary National Certificate in Engineering.

The first thirty-seven pages are devoted to *plane geometry* and cover: perpendiculars and bisectors; the construction of triangles, quadrilaterals and regular polygons; the circle and ellipse; areas and similar figures; plain and diagonal scales; and loci. This is followed by a *solid geometry* section of thirty-four pages covering: oblique, isometric, first and third angle, and auxiliary projection; the projections and sections of solids; developments; and inter-sections. The remaining eighty-three pages deal with the *engineer drawing* of: sectioning and sectional views; dimensioning and tolerancing; screw threads; locking devices; rivets and riveted joints; welds and welding; small tools and gauges; shafts; couplings; bearings; piping; valves and cocks; jigs and fixtures; and electrical circuits and components.

The whole is lavishly illustrated with excellently reproduced example drawings, and a set of practice problems are given for each subject item. Attention has been paid throughout to the relevant British Standards.

Personally, I would have preferred to see the space devoted to the few elementary electrical circuits and components given over to the layout of mechanical drawings on paper, more simple installation drawings using recognized symbols, and references to the compilation of parts schedules and methods used for modification records—as used by industry—unless they are included in the second volume.

An excellent book, produced in a new and attractive style, for those requiring a simple and clear introduction to mechanical engineering drawing.

F.T.S.

FRICTION AND WEAR IN MACHINERY VOLUME 17

Translation from the Russian edited by G. Herrman

(Distributed outside the USA by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 70*s*)

This volume is another contribution to the series of translations made from the original Russian works on the subject matter. Its predecessors, volumes 11–16, were reviewed in the *RE Journals* of September 1963 and March 1965. Its translation and publication was undertaken upon the initiative of the Research Committee of Lubrication of The American National Society of Mechanical Engineers, with the aid of a grant from the National Science Foundation.

The book, first published in 1962, comprises:—

Thirteen papers presenting the results of research work within the field of friction, wear, and lubrication in machines.

The designations and official abbreviations of leading Soviet academies of sciences, engineering institutes, and publishing houses.

An extremely comprehensive bibliography of other Russian publications on the subject matter, and a transliteration table.

With one exception, the authors of the papers are all Russian scientists or engineers of repute. The exception is A. Cameron, a laboratory director of the Imperial College of the University of London, whose paper covers a variety of experiments carried out by the University.

The papers are of a specialist nature, suitable for study by metallurgists, machine designers, and chemists interested in the application of lubricants to machines and vehicles.

F.T.S.

DEVELOPMENTS IN THEORETICAL AND APPLIED MECHANICS—VOLUME 2

Edited by an Editorial Committee under the direction of Dr W. A. Shaw

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price £8)

This 650-page book, a 1965 addition to the Symposium Publications Division of Pergamon Press, records the thirty-five papers presented to the Second Southeastern Conference on Theoretical and Applied Mechanics that was sponsored by the Georgia Institute of Technology, Atlanta, and held at that Institute on 5/6 March 1964. It also includes abbreviated versions of two invited lectures on "Paradoxes in the Theories of Plates and Shells" and "Bending, Buckling and Vibration of Plates with Holes" by Drs H. L. Langhaar, University of Illinois and G. Pickett, University of Wisconsin, respectively.

The papers, whose authors are authoritative members of America Universities, Institutes of Technology, and corporate industrial concerns, cover a variety of subjects in the fields of solid and fluid mechanics, dynamics, plates and shells, and experimental and applied mechanics. All contain information on the latest theories being studied or applied in the USA.

F.T.S.

THE DESIGN OF STRUCTURES OF LEAST WEIGHT

By H. L. Cox

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price £2)

This text book is Volume 8 of Division 1—*Solid and Structural Mechanics*—of the International Series of Monographs in Aeronautics and Astronautics published by Pergamon Press.

Its object is to demonstrate that more attention should be given to the design of a structure for a specific purpose rather than sketch a layout based on past experience and decide the detail by analysis of the distribution of loading in the various components of the layout.

The cost of any structure of a given type is usually the ruling factor when considering most engineering projects and is often more or less proportional to its weight. Therefore, the text illustrates the design procedure, in application to planar and a few three-dimensional structures, on a basis of minimal weight.

After an interesting introduction, in which the author recounts the deliberations of Wm Fairburn and Robert Stephenson on the application of theory to the design of the Britannia Tubular Bridge at Menai some 120 years ago, the text deals specifically with: Structure loading co-efficients and struts; Wide struts; Panels; The design of beams to transmit pure bending; The design of cantilevers; The detail design of braced frames; The basic theory of layout; and Layout in practical design.

The text is only suitable for advanced undergraduates taking civil, mechanical, aeronautical, or structural engineering at universities and colleges of technology. All engineers will, however, appreciate the author's method of concluding his book by quoting Oliver Wendell Holmes' famous *The Deacon's Masterpiece: or The Wonderful "One-Hoss Shay"*—an astounding piece of design logic.

F.T.S.

OSCAR FABER'S CONSTRUCTIONAL STEELWORK SIMPLY EXPLAINED

By John Faber, BSc, MICE, MIStructE

(Published by Oxford University Press, Ely House, London, W1. Price 30*s*)

This is the Fifth (1966) Edition of the original book compiled by Oscar Faber and published in 1927. It is essentially a primer for students commencing courses of instruction on the strength of materials and elementary building construction.

It should be read in association with British Standard No 449 (1965)—*The Use of Structural Steel in Buildings*. In fact, the amendments to this BS since 1959 necessitated the revision of fourth edition of this book.

All the example calculations are worked out in simple algebra and the concise illustrated text explains the Elementary Properties of Steel; Problems of Elasticity; Factor of Safety; Bending Moments and Moments of Resistance; Shear and Web Stresses; Stanchions; Stanchion Bloom—Bases; Riveted and Bolted Connections; Welded Connections.

This book would be of considerable use to trainee architectural draughtsmen within the Corps and could serve as an *aide-memoire* for Clerks of Works. F.T.S.

MATHEMATICAL ANALYSIS

DIFFERENTIATION AND INTEGRATION

By I. G. Aramanovich et al

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 63*s*)

This is volume 81 of the International Series of Monographs in Pure and Applied Mathematics published by Pergamon Press.

It was translated from the Russian by H. Moss and the English edition was edited by I. N. Sneddon, Simson Professor of Mathematics, University of Glasgow.

The text is devoted to two basic operations of mathematical analysis—differentiation and integration—and discusses the complex of problems directly connected with them in functions of one or several variables. Included are chapters dealing with: Composite and Implicit Functions of *n* variables; Systems of Functions and Curvilinear Co-ordinates in a Plane and in Space; Improper Integrals, Integrals dependent on a Parameter, Stieltjes Integral; The Transformation of Differential and Integral Expressions.

A number of appendices give tables of Derivations of Elementary Functions; The Expansion of Elementary Functions into Power Series; Integrals of Elementary Functions; Special Functions defined by Integrals.

The book will be of value to undergraduate physicists and engineers interested in applied mathematics.

F.T.S.

TURBINE MAIN ENGINES

By J. B. Main, AMIMechE, MIMarE; F. R. Harris, ACGI, BSc(Eng); C. W. Herbert, MIMechE, MIMarE

(Published by Pergamon Press Ltd, Headington Hill Hall, Oxford. Price 30*s*)

This soft-covered book is included in the Marine Engineering Division of The Commonwealth and International Library.

The contents are divided into three parts. Part 1—Marine Steam Turbines, by J. B. Main, Head of New Ship Design, Shell International Marine Ltd, London; Part 2—Marine Gas Turbines by F. R. Harris, Chief Engineer Large Steam Turbine Dept of AEI Ltd, Manchester; Part 3—Free Piston Gas Turbine Machinery, by C. W. Herbert, Engine Works Manager (Tech) Smiths Docks Ltd, Middlesbrough.

All three parts are a useful blend of fundamental theory and practical application. As a whole the book takes a place between purely theoretical text-books and user's instructional handbooks, the result is an excellent introduction to the subject matter for engineering apprentices.

Part I is largely devoted to the theory of steam turbines and the methods of starting and operation; but in Parts 2 and 3 a shorter amount of theory is supplemented by descriptions of a variety of commercial marine engines of their respective types. Parts 2 and 3 are also well illustrated with sectional drawings and include main cycle details and comparative construction and performance tables.

A very good primer indeed.

F.T.S.

Technical Notes

CIVIL ENGINEERING

Notes from *Civil Engineering and Public Works Review*, October/November 1965.

BAMBOO-REINFORCED SOIL-CEMENT WITH SPECIAL REFERENCE TO ITS USE IN PAVEMENTS. The October and November issues include parts of a paper on bamboo-reinforced soil-cement. The paper will be contained in following issues. It is generally agreed that bamboo reinforcement in concrete is not practical because of the low transfer of stress from concrete to bamboo (Modular Ratio < 1). However the authors of the paper feel that there is a case for bamboo-reinforced soil-cement for use as bonded underlay for pavements. In view of the cheapness and probable availability of the materials concerned (7 to 15 per cent of cement in the soil-cement mix) in certain areas it is felt that the results of the experiments are of interest to military engineers. Parts 1 and 2 deal with the establishment of values for bond and flexural stresses and it is assumed that subsequent parts will deal more directly with the bamboo reinforced pavement underlay.

REINFORCED PLYWOOD BEAMS (October issue). Some preliminary experiments at The Queen's University of Belfast indicate that plywood beams reinforced with steel bars compare favourably with steel beams. Although work in this field is very much in the experimental stages, the possibilities are of interest to anyone concerned with structural design.

A THEORETICAL TREATMENT OF THE ELECTRO-OSMOTIC CONSOLIDATION OF SOILS. (October issue). This paper is of interest for two reasons; firstly a theory has been evolved which predicts accurately the settlement produced under an applied electric potential and secondly it is noted that this paper forms part of a general investigation into the practical uses of electro-osmosis being carried out in the Division of Civil Engineering, University College of Swansea.

NUCLEAR EXCAVATION (November issue). Nuclear excavation offers exciting possibilities in earth removal. This short article gives the relationship so far agreed upon between crater diameter and depth and yield of explosive charge. The article goes on to examine some of the associated problems with particular reference to the creation of a sea-level canal joining the Pacific Ocean and the Carribean Sea. T.H.S.

Notes from *Civil Engineering and Public Works Review*, December 1965 and January 1966

ROCK MECHANICS IN CIVIL ENGINEERING WORK. The science of rock mechanics is now well established as a branch of engineering geology. It seeks to investigate the behaviour of rock masses, and has obvious application to the design and construction of civil engineering works. Foundation problems, stability of rock slopes, water-bearing characteristics and rock tunnelling are all within its scope. The December and January issues contain the first two of a three part article which outlines present day knowledge, methods and equipment in this field. Questions of site investigation, the behaviour of rock masses under changed conditions, and the vital influence of joint structure are discussed. The final article will deal with the application of rock mechanics to the design of civil engineering works in rock.

INTERNATIONAL CODES FOR REINFORCED AND PRESTRESSED CONCRETE. For a number of years now two International Committees have been working steadily towards the unification of Codes of Practice for structural concrete. They are the European Committee on Concrete (CEB) and the International Federation of Prestressing (FIP). Progress made by both these bodies was reviewed recently at a meeting in London. A considerable advance has been made towards common design principles for reinforced concrete, and many countries, from Belgium to Brazil, have already revised their Codes to conform with the CEB "Recommendations for an International Code of Practice for Reinforced Concrete" published in 1962. In this country the Institution of Structural Engineers, on behalf of the British Standards Institution, is now preparing the revision of several Codes of Practice, including those for Reinforced Concrete (C.P.114), Prestressed Concrete (C.P.115) and Load-Bearing Walls (C.P.111). It is almost certain that many of the recommendations of the CEB will be followed, particularly the adoption of the "limit-state" approach as a basic design philosophy. Draft revisions of our Codes should be in circulation by the end of 1966.

The work of the FIP has not advanced quite as far, but an important publication covering design and construction recommendations for prestressed work is due to appear when the International Prestressing Congress meets in Paris this summer.

THE CIVIL ENGINEERING TECHNICIAN TRAINING SCHEME. In a short article in the December issue, Mr M. D. Noar, Secretary of the Civil Engineering Technician Training Scheme, describes the aims and aspirations of the scheme. Set up jointly by the Institution of Civil Engineers, the Institution of Municipal Engineers, the Association of Consulting Engineers, and the Federation of Civil Engineering Contractors, the scheme hopes to organize regular training programmes (mainly of the "sandwich" type) for the aspiring technician. The standards will be less rigorous than those necessary for corporate membership of the Institutions concerned, and will seek to ally academic work of Ordinary National Certificate standard with sound practical training. It is hoped that eventually a recognized qualification as a Civil Engineering Technician will be a valuable step towards advancement as an Inspector of Works, site agent, and similar appointments. The scheme will clearly interest the military Clerk of Works, Draughtsman C & S and others.

FORMWORK. The December issue contains a special FORMWORK FEATURE comprising an Introduction and seven articles. Quoting from the Introduction "Formwork plays a vital role in concrete construction. It comprises the mould into which the concrete is placed, therefore the resulting dimensional accuracy, surface finish, structural efficiency and durability of the concrete are all controlled or affected by its construction and performance". The seven articles range from recent research into the pressure of concrete on formwork to the report of a recent Symposium on Formwork design and specification. To the average engineer, who is often quite content to let the joiner design as well as construct the formwork, a glance through these articles can be revealing as well as instructive.

STRESS DISTRIBUTION IN LOAD BEARING BRICKWORK. An article in the January issue describes recent investigations into the stress conditions in brickwork. In the past most buildings constructed in brickwork were not designed on an engineering basis, but were made sufficiently strong by ensuring that there was ample thickness of material to keep stresses down to very low values. New methods of design and calculation have resulted in thicknesses of brickwork being kept to a minimum and stresses to a safe maximum. Some of the results of the present investigation are surprising; for example, the common idea that the load distribution over a lintel is triangular is shown to be completely false.

PLASTIC SEAWEED. This month's novelty is undoubtedly the use of plastic "seaweed" (in America need it be said) to retard beach erosion. Details in the January issue.

C.F.R.

THE MILITARY ENGINEER

SEPTEMBER–OCTOBER 1965

THE EARTH TREMBLES. By R. E. Curtis. A short resume of what is known of the causes of earthquakes and the areas of the world where they are most frequent. The work being carried out by seismologists in all countries is described and there are interesting illustrations. In spite of the great advances that have been in this science prediction is still not possible with any accuracy.

PETROLEUM EQUIPMENT FOR MOBILITY. By Col J. Kerkering, US Army (retd). This article describes equipment that has been provided for the supply and distribution of fuel in a theatre of war. It consists of a means of providing offshore mooring berths for tankers by means of mooring buoys which are held in place by anchors which are explosively embedded into the bottom of the sea, storage tanks which are fabric-coated containers which pack into 3 by 13 ft rolls and which have a capacity of 420,000 gallons, and an assault hose line the heart of which is a 4-in flexible hose laid from a moving truck. Booster pumps at 2¾ mile intervals pump fuel at the rate of 225 gallons a minute. There are good illustrations.

MILITARY GEOGRAPHY OF INDOCHINA. By James A. Reynolds. A short, clear description of the physical geography of Indochina which helps in an understanding of the campaign which is being fought there.

ELEVEN MILES OF FOUNDATION. By Col James B. Meanor, Corps of Engineers. This is a description of the City of St Louis Flood Protection Project which was begun in 1959 and which is well under way. It is essentially an earth and concrete dam some eleven miles long traversing one of the densest industrial, communication, utility, and waterfront centres in the United States. Considerable detail is given and there are good illustrations. The design of the floodwall depends on the immediate sub-surface conditions and the different designs are described.

SATELLITE TRIANGULATION. By Lawrence W. Swanson, Captain US Coast and Geodetic Survey (retd). The Coast and Geodetic Survey is now ready to begin a new method of determining a world wide geodetic satellite triangulation network which will provide control points for the absolute determination of the size and shape of the earth. This article describes the way in which this is to be carried out and the role of the satellite.

CROSSING FROZEN RIVERS IN KOREA. By Maj Robert A. Purple, Corps of Engineers. This article describes the various experiments carried out by an Engineer Battalion in Korea to find out how best to provide crossings of frozen rivers using expedient methods with the standard bridging equipment. There are good illustrations and the ways in which the equipment were used is clear. It was found that it was perfectly possible to provide effective crossings by the use of components from the M4T6 bridging set.

LUNAR EXPLORATION SYSTEMS. By Maj Daniel L. Lycan, Corps of Engineers. Lunar Exploration Systems for Apollo (LESA) have been studied during the past two years under the direction of the National Aeronautics and Space Administration (NASA). In the initial concept a modular system of facilities was outlined which could support a variety of lunar missions. This was described in an article in the *Military Engineer*, May–June 1965. A study of the engineering and operational aspects of the various base sub-systems that would be needed has followed. These included power, vehicular engines and fuel, life support, communications, scientific equipment, operations and logistics and deployment methods. The results of the study of those parts of the project which are the responsibility of the Corps of Engineers are described in this article. They are power, vehicular engines and fuel, and deployment methods. There are illustrations of model set-ups.

SEABEES IN AMPHIBIOUS OPERATIONS. Lieut-Comdr W. W. Gentry, Civil Engineer Corps, US Navy. This is an account of an exercise involving an assault landing on beaches in southern Spain.

MILITARY ENGINEER FIELD NOTES

BANDING A TECHNIQUE OF FORM CONSTRUCTION. By Capt Peter F. Lagasse, Corps of Engineers. This is a description of a method of constructing forms for concrete work using ¾-in plywood and ¾-in steel bands applied with a hand-operated banding machine. There is ample detail given and it is claimed for the method that it is simple and economical in material.

ELECTRICAL PRESSURE TRANSDUCERS. An Application. By Capt Hugh P. Johnson, Corps of Engineers. Differential settlements in the foundations of certain structures, for example missile launching facilities, cannot be tolerated and the accurate prediction of earth settlement under static and dynamic loads is of great importance. This article describes the factors governing soil stability under pressure and describes how electrical pressure transducers can be used to assist in the study of the subject though it is not claimed that their use is the answer to the problem of settlement prediction.

J.S.W.S.
