THE ROYAL ENGINEERS JOURNAL—MARCH 1957

VOL. LXXI. No. 1

THE ROYAL ENGINEERS JOURNAL

Vol. LXXI MARCH 1957 No. 1

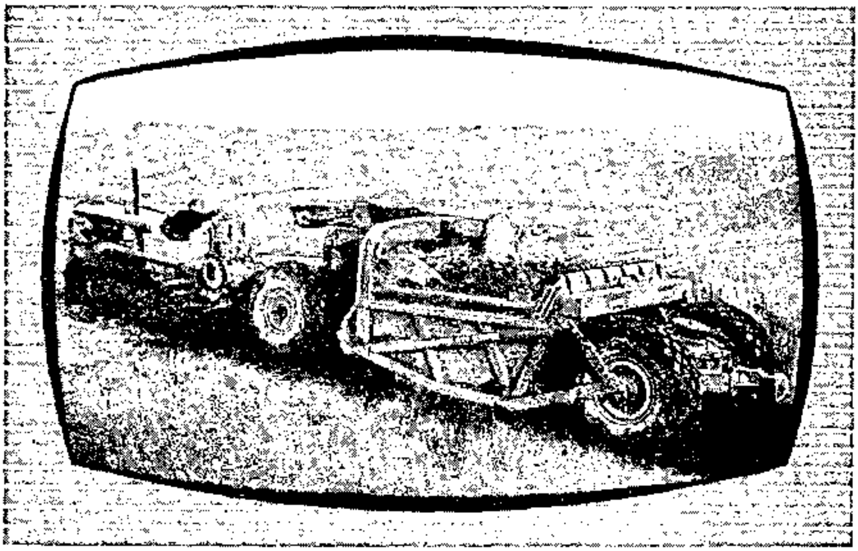
CONTENTS

Nuclear Power Engineering—1957	Lieut.-Colonel J. E. L. Carter	1
The History and Development of the Bucket Excavator	Captain P. A. Camp	22
Water Divining as an Aid to Engineering	Colonel H. Grattan	33
The Erection of Buildings in East Africa to Accommodate a Combined Army and R.A.F. Wireless Project	Major E. A. Shand	43
The Suez Canal	Lieut.-Colonel E. W. C. Sandes	55
The R.E. Headquarters Mess	Colonel J. M. Lambert	59
Red Patch	The Late Colonel A. C. Mitchell	72
Presentation of a Pair of Candelabra to the Officers of the Royal New Zealand Engineers by the Officers of the Royal Engineers		82
Correspondence, Memoirs, Books Reviews, Technical Notes		83

PUBLIS... ...ERS

All corr... ...tion

AG... ...I



THE COUNCIL OF THE INSTITUTION OF ROYAL ENGINEERS

(Incorporated by Royal Charter, 27th February, 1923)

Patron—HER MAJESTY THE QUEEN

President

Major-General Sir A. Douglas Campbell, K.B.E., C.B., D.S.O., M.C., M.A.	1957

Vice-Presidents

Major-General J. C. Walkey, C.B., C.B.E.	1955
Brigadier A. G. Bonn, C.B.E., M.C., M.I.C.E.	1957

Elected

Brigadier H. P. Drayson	1954
Lieut.-Colonel F. E. Ladly, M.B.E., E.R.D., M.R.San.I., A.I.Mun.E.	1954
Brigadier J. K. Shepheard, D.S.O., O.B.E., B.A.	1954
Colonel W. B. Sykes, C.B.E., T.D., M.I.Struct.E., M.Soc.C.E. (France), M.S.E.	1954
Major-General B. T. Wilson, C.B., D.S.O.	1954
Major E. L. Wilson, M.C.	1954
Colonel C. J. Godfrey, B.Sc.	1955
Lieut.-Colonel A. J. le G. Jacob, M.B.E., B.A.	1955
Colonel A. R. Mais, O.B.E., T.D., D.L., B.Sc., F.R.I.C.S., M.I.Struct.E., M.Soc.C.E....	1955
Lieut.-Colonel J. A. Rawlence, O.B.E., B.A., A.R.I.C.S.	1955
Captain C. B. Pollard	1955
Colonel K. F. Daniell, O.B.E., B.A.	1956
Colonel P. F. Hayes, O.B.E., B.A.	1956
Brigadier L. J. Harris, O.B.E., B.A., F.R.I.C.S.	1956
Lieut.-Colonel F. A. Rayfield, M.I.C.E., M.I.Mun.E.	1956

Ex-Officio

Brigadier T. I. Lloyd, C.B.E., D.S.O., M.C.	D.E.-in-C.
Colonel B. S. Armitage, D.S.O.	A.A.G., R.E.
Brigadier G. W. Duke, C.B.E., D.S.O., B.A.	Comd., S.M.E.
Brigadier C. H. Barnett, M.A., M.Inst.T.	D.Tn.
Major-General G. A. T. Pritchard, C.B.E.	D.F.W.
Brigadier L. D. de V. Carey, C.B.E.	...Dir. of Mil. Survey
Colonel J. de V. Hunt	... D/Comd., S.M.E.
Brigadier F. W. Houghton, D.S.O., M.C.	Comd., Trg. Bde., R.E.

Corresponding Members

Lieut.-Colonel A. R. Currie, D.S.O., O.B.E., *New Zealand Military Forces*	1st January, 1949
Colonel E. H. Webb, D.S.O., C.D., *Canadian Army*	1st November, 1954
Colonel C. Linsell, O.B.E., M.C., *Union Defence Force, South Africa* ...	1st February, 1956
Brigadier P. P. Jackson, *Australian Military Forces*	21st September, 1956

Secretary and Editor R.E. Journal

Brigadier C. C. Phipps, C.B.E., M.C.	13th January, 1945

Bankers

Lloyds Bank, Ltd., Cox's and King's Branch, 6 Pall Mall, S.W.1.

4,050 1.3.57

THE ROYAL ENGINEERS JOURNAL

Authors alone are responsible for the statements made and the opinions expressed in their papers

VOL. LXXI

CONTENTS

MARCH, 1957

PAGE

1. NUCLEAR POWER ENGINEERING—1957. BY LIEUT.-COLONEL J. E. L. CARTER, M.B.E., M.C. (*With Photographs and Sketches*) 1
2. THE HISTORY AND DEVELOPMENT OF THE BUCKET EXCAVATOR. BY CAPTAIN P. A. CAMP, R.E. (*With Photographs and Sketches*) 22
3. WATER DIVINING AS AN AID TO ENGINEERING. BY COLONEL H. GRATTAN, C.B.E. (*With Sketch and Plan*) 33
4. THE ERECTION OF BUILDINGS IN EAST AFRICA TO ACCOMMODATE A COMBINED ARMY AND R.A.F. WIRELESS PROJECT. BY MAJOR E. A. SHAND, R.E. (*With Photographs*) 43
5. THE SUEZ CANAL. BY LIEUT.-COLONEL E. W. C. SANDES, D.S.O., M.C., R.E. (RET.) 55
6. THE R.E. HEADQUARTERS MESS. BY COLONEL J. M. LAMBERT, O.B.E. (*With Photographs and Line Drawings*) 59
7. RED PATCH. BY THE LATE COLONEL A. C. MITCHELL, O.B.E. 72
8. PRESENTATION OF A PAIR OF CANDELABRA TO THE OFFICERS OF THE ROYAL NEW ZEALAND ENGINEERS BY THE OFFICERS OF THE ROYAL ENGINEERS. (*With Photograph*) 82
9. CORRESPONDENCE 83
10. MEMOIRS 85
    - LIEUT.-GENERAL SIR GORDON N. MACREADY, BART., K.B.E., C.B., C.M.G., D.S.O., M.C. (*With Photograph*) . . . . G.S.M.B.
    - COLONEL SIR GERALD PONSONBY LENOX-CONYNGHAM, KT., M.A., F.R.S. (*With Photograph*) . . . . J. de G.-H.
    - BRIGADIER SIR HAROLD J. COUCHMAN, KT., D.S.O., M.C. (*With Photograph*) C.G.L.
11. BOOK REVIEWS 92
    - CANADIANS IN ITALY . . . . B.T.W.
    - THE SOVIET ARMY . . . . B.T.W.
    - THE KING'S AFRICAN RIFLES . . . . B.T.W.
    - BRIDGING THE YEARS . . . . J.P.F-S.
    - DUMPY LEVEL WORK . . . . J.H.G.S.
    - BRITISH RAILWAY TRACK DESIGN, CONSTRUCTION AND MAINTENANCE D.F.D-B.
    - THE ULTIMATE LOAD THEORY APPLIED TO THE DESIGN OF REINFORCED AND PRESTRESSED CONCRETE FRAMES . . . . J.M.
    - THE PRINCIPLES OF MECHANICS . . . . J.P.F-S.
    - AVIATION CARTOGRAPHY . . . . C.C.P.
    - THIRD REPORT FROM THE SELECT COMMITTEE ON ESTIMATES. SESSION 1955–56 C.C.P.
    - INFINITE SEQUENCES AND SERIES . . . . J.P.F-S.
    - ASYMPTOTIC EXPANSIONS . . . . J.P.F-S.
    - CALCULUS, REFRESHER FOR TECHNICAL MEN; TRIGONOMETRY, REFRESHER FOR TECHNICAL MEN . . . . C.C.P.
12. TECHNICAL NOTES 98
    - THE ENGINEERING JOURNAL OF CANADA
    - THE MILITARY ENGINEER
    - CIVIL ENGINEERING

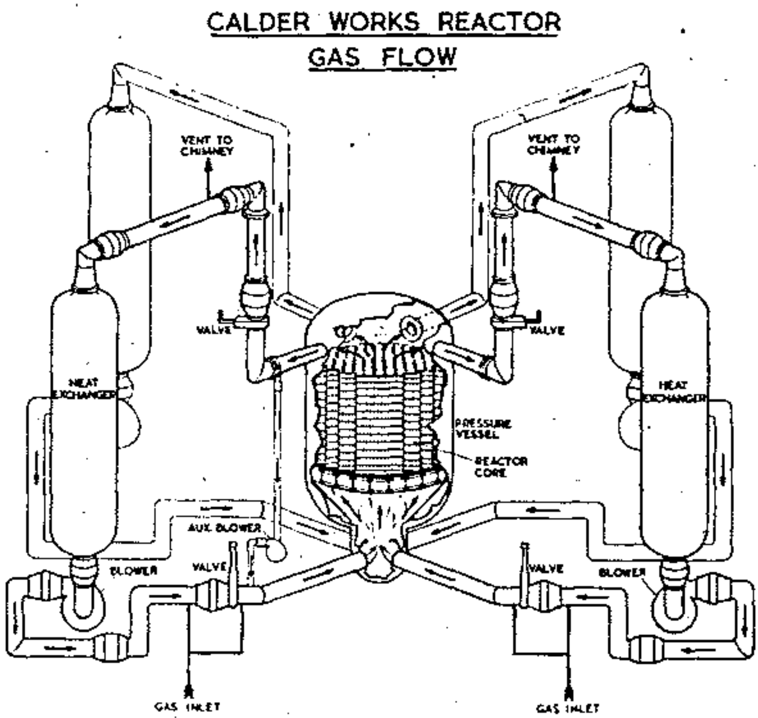


Fig. 1.—Calder Hall reactor gas flow diagram.

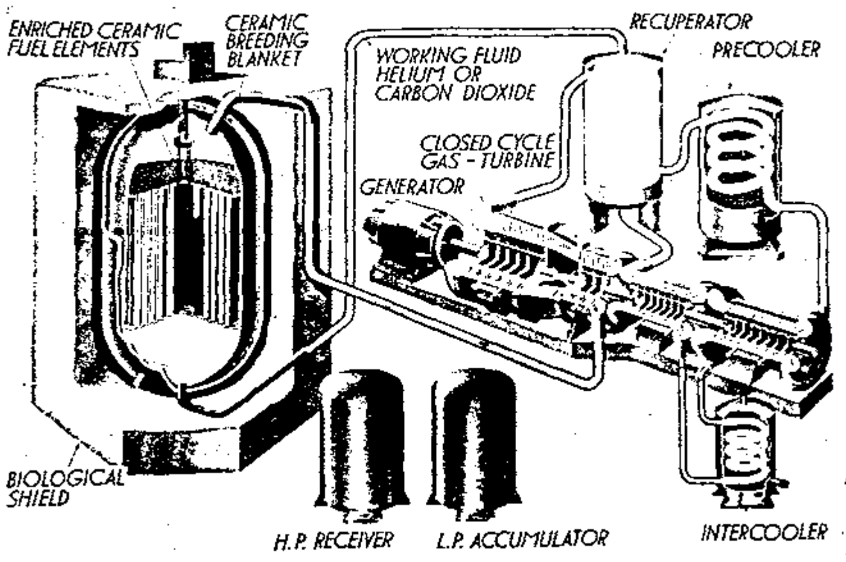


Fig. 2.—Diagram of high pressure gas cooled reactor driving gas turbine on closed circuit.

Nuclear Power Engineering—1957

By Lieut.-Colonel J. E. L. Carter, M.B.E., M.C.

"The stakes are high but the final reward will be immeasurable. We must keep ourselves in the forefront of the development of nuclear power so that we can play our proper part in harnessing this new form of energy for the benefit of mankind."

So, in words prosaic if not platitudinous, ends a document, the White Paper on "A Programme of Nuclear Power," Cmd. 9389, of 1955, in which, looming through the black mists of necromancy, we can see dimly the processes by which we can distil, drop by drop, new life-blood of power for the sinews of the industrial world on which we so utterly depend.

Since the general raising of security barriers two years ago a flood of literature on nuclear power has tended to engulf the engineering world; but none the less it is still difficult for the average engineer, let alone the man in the street, to comprehend the nature of the revolution taking place, the values of the stakes referred to in the White Paper, and the measure of the immediate and long-term rewards. The aim of this paper is to explain some of the more important aspects of these matters in simple terms for the benefit of the average engineer officer, and to draw attention to various trends of development which in due course will certainly affect his work. The paper has been made possible largely because the author was privileged to attend the first Senior Technical Executives Course on Nuclear Energy which was run by A.E.R.E. Harwell at Oxford last August mainly for the benefit of senior staff of the C.E.A. and of industrial firms engaged in the nuclear energy field. So it may be said that a secondary aim of the paper is to pass on to the Corps as a whole the benefits of a most fascinating ten-day course the author attended on its behalf. The substance of this article comes largely from lectures given on this course, supplemented by information from the short bibliography listed at the end of the paper and a few items that have appeared in the popular and technical press. The opinions expressed are mainly the author's own.

U.K. Forecast Electric Power Demand

In the White Paper it is stated that on conservative estimates, arrived at by various different means, the demand for electricity in this country will increase by a factor of 3½ in the twenty years from 1955 to 1975. In 1954, 215 million tons of coal were produced from deep mines in this country and 40 million tons were used for the generation of electric power. Allowing for the development of hydro-electric power and for improvements in thermal efficiency the requirements of fuel for electric generation would be equivalent to 65 million tons of coal in 1965 and 100 million tons in 1975. The prospects of meeting this requirement with either coal or oil seem utterly remote.

"You know," said one of the C.E.A. engineers on my course, "until this business of nuclear power as a practical possibility came up almost out of the blue, we were scheduling an enormous power station construction programme without having the faintest idea where the fuel was coming from." To this country, and certain others, notably France, the wholesale use of nuclear power is in fact a matter of industrial life and death. To others, such as the United States, it is more a matter of normal industrial progress. Thus it is the United Kingdom's nuclear power programme which in many ways is attracting the prime attention of the nuclear engineering world.

It is important at this stage to appreciate the size of the programme. The installed generating capacity in this country in 1955 was about 20,000 MW., i.e., 20,000,000 kW. An increase of 3½ times in power requirements does not involve a proportionate increase in generating capacity. In fact it is estimated that 57,000 MW. will be required by 1975. To reach this figure, allowing for the replacement of stations that will become obsolete in the twenty-year period, about 45,000 MW. of capacity will have to be built. The cost of this in conventional form would be about £2,500,000,000. Nuclear power stations, though cheaper to run, are more expensive to build. If, as is expected, a very substantial part of the new construction is nuclear powered, the total cost of the twenty-year programme may be in the order of £4,000,000,000, a fairly tidy sum to inject into the engineering economy of a country as small as ours. This, however, is only part of the picture. Taking into account the military aspects of the industry and the other civilian aspects which will be discussed later in this paper, it can well be appreciated that nuclear engineering both in its importance and its scale has become a major feature in the engineering world of today. Therefore, whatever may be its detailed military applications, it is a subject with which every Royal Engineer officer should make himself at least generally familiar.

The White Paper Programme

The stations now being built by the U.K. Atomic Energy Authority at Calder Hall and Chapel Cross have as their prime aim the production of plutonium for military purposes. As such they do not come within the White Paper programme, although they will, in fact, provide some power for the grid. They are, however, forerunners in type of the first stations of the programme, and as such are of considerable interest. The programme may be summarized as follows:—

(*a*) The construction of two gas-cooled, graphite-moderated stations (each with two reactors) to start in 1957 and come into operation about 1960–1.

(*b*) The construction of two similar, but improved stations, starting about eighteen months later.

(*c*) The construction of a further eight stations in two groups of four in the period 1960–5. Some at least of these stations would differ in type from the earlier ones and are regarded as stage two stations.

This covers the first ten years of the programme. The power output from the first four stations was estimated to be between 400 and 800 MW., and of the last eight well over 1,000 MW., giving a total of something like 2,000 MW. In fact, for reasons which will appear later, this part of the programme seems to be already well out of date in that, as detailed design and development proceeds, the capacities of the first stations are seen to be well in advance of the White Paper figures. This indicates a general quickening of the programme to an extent which has not yet been clearly announced. As regards coal saving, the White Paper forecast that by 1965, nuclear power stations, working entirely on base load, would be producing power equivalent to 5 to 6 million tons of coal a year. This, however, should also be substantially exceeded.

For the second ten years of the programme there is envisaged a process which might best be described as a Hallow-ee'n jet-propelled ride from a decade of fantasy to one of witchcraft; for then stage three reactors, using fissile and fertile materials arising from the earlier reactors, are scheduled to produce not only ever increasing quantities of power, but, at the same time, ever increasing quantities of nuclear fuel. The first fast breeder reactor of this type, a 60 MW. experimental model, is under construction already, in a vast steel ball, on the far north coast of Scotland, at Dounreay. In charge of this work is Major-General (retd.) S. W. Joslin, C.B., C.B.E., whose name can be found in the retired lists of regular officers of the Corps as well as of his later love, the R.E.M.E.

Enough, now, of the programme. The time has come to examine more carefully some of the remarkable statements in the paragraphs above, for in the understanding of them lie the first steps towards the understanding of the problems of the nuclear engineer. The most convenient starting point for this examination is a consideration of the materials that form, or can be formed into, nuclear fuels.

Fissile and Fertile Elements

Fissile elements are the nuclear fuels. Fertile elements are those that can be transmuted into fissile elements by a process of nuclear bombardment. There is only one naturally occurring fissile material; this is the isotope of uranium known as U235. This occurs as a small fixed proportion, 0·7 per cent, of all natural uranium, and can be produced in a pure form only with the very greatest difficulty.

Only two fertile elements are found. One is the isotope of uranium known as U238 which forms 99·3 per cent of natural uranium. Under nuclear bombardment this can be changed into the fissile element plutonium, which exists only as an artificially created element, and which has characteristics similar to U235 as a nuclear explosive or fuel. It has, however, the advantage of being fairly readily separable from its parent element U238. The other naturally occurring fertile element is thorium232. This is the only constituent of natural thorium, and can be changed into the fissile element uranium233, an isotope of uranium which does not occur naturally.

The primary methods of producing nuclear power depend on using the extremely small amounts (1 part in 140) of U235 in natural uranium. The significance of the fertile materials lies largely in the fact that reactors, such as the one being built at Dounreay, can be made which will convert more fertile material into fissile material than they consume of fissile material in the process. The best analogy is to imagine a coal-burning furnace that can be packed around with some special form of gravel such that, for every ton of coal burnt and without using up any of the heat generated, one and a half tons of the gravel is converted into a further supply of coal or coke. This means quite simply that apart from a certain amount of wastage, all natural thorium (fertile Th232) and all natural uranium (0·7 per cent fissile U235 and 99·3 per cent fertile U238), can in due course be consumed as nuclear fuels.

Prospecting for these elements is far from complete, but already ample supplies have been discovered throughout the world. In the free world the main sources of uranium are in Canada, the Belgian Congo, the United States and the Union of South Africa, with lesser sources in Australia, France, various French overseas territories and Portugal. The potentially large producers of thorium which, it must be remembered, is not immediately required, are India, Brazil and Madagascar.

The Source of Energy

The three fissile elements, uranium 235, plutonium and uranium 233 have one characteristic in common. When struck by neutrons their atoms break into two somewhat unequal parts and in this process emit energy and also more neutrons than they absorb. This process is known as fission and, as everyone knows, can be made into a chain reaction, the neutrons from one disintegrating atom causing fission in other atoms with an intensely rapid build-up of energy, as in the atomic bomb. The energy is released largely as heat, but also to some extent as highly lethal forms of radiation. During the fission process every atom does not break into exactly the same parts, so that in fact quite a range of fission products are formed. The main characteristic of these is that they are almost all intensely radio-active and hence impose a very serious health hazard.

The source of the energy of fission is the destruction of matter in the process of fission. It can be shown by relatively simple physical experiments that the mass of all the products of the fission of U235 is about 0.1 per cent less than the mass of the U235 before fission. In other words about one gram out of each kilogram disappears in the process. The energy liberated can be calculated very simply from Einstein's famous equation

$$E = mc^2$$

where E and m are energy and mass respectively and c is the velocity of light in a vacuum. For a mass loss of one gram, knowing that c is 3×10^{10} cm. per sec., the energy liberated is simply 9×10^{20} ergs. This equals 25 million units of electricity (about £50,000 worth at a halfpenny a unit) or in round numbers 1,000 MW. days.

As natural uranium contains about 0·7 per cent of U235, each ton contains about 7 kg. and thus has a potential mass loss of 7 gm. The potential fuel value is therefore 7,000 MW. days. With present technology, however, only rather less than half of this can actually be utilized. The figure used in the White Paper as the basis of all calculations is 3,000 MW. days per ton.

It must be clearly appreciated that these figures are simply a measure of the available heat. This can be converted to electricity at present only through some conventional steam-driven, or possibly gas-driven, electric generating plant. This might have a thermal efficiency of about 25 per cent, so that the amount of electricity that can be obtained at present from a ton of uranium is about 25 per cent of 3,000 MW. days, i.e., 750 MW. days.

The cost of processed natural uranium is about £15,000 a ton, giving a fuel cost of about 0·18d. per unit of electricity generated. In effective heat value one ton of uranium is equivalent to 10,000 tons of coal. Very little mental arithmetic is needed, therefore, to show how much cheaper uranium is as a fuel than coal, particularly where the latter has to carry high freight charges. However, as will emerge later, the cheapness of atomic fuel is at present to some extent nullified by the high cost of nuclear power stations.

All the above figures have referred to the straightforward "burning" of the 0·7 per cent of fissile material in natural uranium. When, however, breeder reactors are available the greater part of the 99·7 per cent of fertile material in natural uranium will be convertible into fissile material. In these circumstances the calorific value of one ton of uranium or thorium can be compared with that of 1,000,000 tons of coal. Thus, using breeder reactors of the Dounreay type, the 1975 electric power requirements of this country, 3½ times that of 1955, and equivalent to a 100,000,000-ton coal consumption, could be produced from the consumption of 60 tons of uranium having the ridiculous basic cost of £100,000.

Vast sums of money will have to be spent before these ambitions can be converted into achievements, but the fact remains that the problems to be solved now are essentially engineering ones and not those of atomic physics.

The First Reactor Phase

Having looked a little into the dim but exciting future of the immeasurable rewards of the White Paper we must return now to the sober realities of the present.

Owing to its very low concentration of fissile material, natural uranium is a very difficult fuel to "burn". It is rather like the carbonaceous fuel containing more stone than coal that we have all struggled with from time to time. Two courses are open; to face the difficulties of using the uranium in its natural state or to improve the fuel by increasing the concentration of fissile material in it. Both, unfortunately, are easier said than done. It is convenient to consider first the problems involved in increasing the concentration of fissile material in natural uranium. The two constituents of natural uranium, U235 and U238, are isotopes. This means that they are chemically identical, and physically differ only owing to their slightly different atomic weights of 235 and 238 respectively. They can therefore be separated only by some physical process depending on this slight difference in atomic weight. Several processes are possible; all are tedious and expensive. The one used in this country, at Capenhurst, is to convert the uranium to uranium hexafluoride UF6, a highly poisonous, corrosive and thoroughly unpleasant gas, and pump this through a series of special membranes. The slightly heavier molecules of gas incorporating the U238 atoms diffuse slightly more slowly than the others and a gradual separation can be effected. Some idea of the scale of effort required and the costs involved can be obtained from the following approximate U.S.A. figures;

Cost of plant to process 1,000 tons of uranium a year, £100,000,000.

Annual production of uranium containing 90 per cent U235, 3·35 tons.

Actual weight of U235 in the above, 3·01 tons.

Electric power needed continuously, 560 MW. costing £56,000 a day at 1d. a unit.

The cost of 1,000 tons of natural uranium is £15,000,000.

On American figures 3 tons of U235 in this form is worth £30,000,000.

It can therefore be deduced that the cost of separation is in the order of £5,000,000 per ton of U235 produced. Plants of this type were set up in the U.S.A. and this country because at one stage they were the only way to produce the relatively pure fissile material required for nuclear weapons. Surpluses of such material above military requirements are already available in the U.S.A., but in this country, at least at present, the costs involved and the need to satisfy military requirements has swung the balance against the use of enriched fuel in the first phase of the White Paper programme.

Now let us consider the alternative course, the use of natural uranium in an economic and commercially acceptable reactor. The first stage in this is a discussion of the principles involved, and the second a consideration of the type of reactor design that has been accepted for the first phase of the programme.

Natural Uranium Reactors

It has already been pointed out that when a U235 atom splits after being struck by a neutron additional neutrons are given out. In fact on an average 2·5 neutrons are emitted for every one absorbed, so that there is a net gain of 1·5 neutrons per fission. If these could all be applied to building up the chain reaction no difficulty would arise. In fact, however, many of these neutrons are lost, either through being absorbed in the U238 which forms so much of the greater part of the fuel material, or in impurities, or by escaping from the reacting mass. Furthermore it is clear that the situation will steadily deteriorate as the reaction proceeds, partly because the wide range of fission products formed includes some which have very high capacities for absorbing neutrons and partly because the concentration of U235 will fall as it is used up. Thus efficiency of reactor design determines not only whether the reactor will work at all with natural uranium, but the amount of "burn up" which can be achieved, i.e., the proportion of the potential 7,000 MW. days per ton which can in fact be converted into heat. The whole problem is essentially one of the proper utilization of the available neutrons and, in the jargon of the subject, is called the problem of neutron economy. It is largely a matter of reducing to practical nuclear engineering possibilities a number of the highly significant facts of nuclear physics. These facts and the engineering consequences are as follows:—

(*a*) Neutrons from fissions emerge at high speeds. Neutrons travelling at high speeds are much more likely to be absorbed by U238 than to cause fissions in U235. Certain elements have the property of slowing down neutrons without absorbing them. These are called moderators. The best is heavy water, but the most economic for this country is highly purified graphite. Thus one main problem of design in reactors of this type, so-called thermal reactors, because the neutrons have been slowed down to the normal speeds associated with their temperature, is the arrangement of fuel elements and graphite moderator in the pattern most suitable for achieving neutron economy.

(*b*) Neutrons tend to fly out and escape from the reacting core. To minimize this effect the core is surrounded with a material that has the power of reflecting neutrons without absorbing them. Graphite again is suitable for this.

(*c*) All materials in the reactor must be extremely pure and particularly free of any elements that have a high capacity for absorbing neutrons.

(*d*) The reacting core must be of a certain minimum size. This is because no reflector can be perfect, and therefore a sufficient concentration of neutrons can be built up only by having a sufficient quantity of fissile material. This is called the critical size and is naturally far larger for natural uranium than for the highly concentrated fissile material used in an atomic bomb.

Provided the conditions listed above are satisfied the reactor will work; but the following additional requirements must be met before it can be controlled and made to yield useful power:—

(*a*) Some means must be provided of controlling the reaction once it starts. Otherwise the reactor will simply run away. This is relatively simple. The problem is merely one of controlling the supply of neutrons, and this is done by moving into or out of the reacting core control rods made of some material with a high capacity for absorbing neutrons. As these rods are withdrawn reactivity rises, as they are inserted it falls. Emergency shut-down rods can also be provided held ready above the reacting core to drop into it should some nuclear crisis arise. Boron is a suitable material for these rods.

(*b*) A reactor can be controlled only if its reactive state can be observed. This is mainly a matter of relatively straightforward electronic instrumentation designed to show at any given moment the neutron state and rate of change. Automatic controls and electronic or mechanical safety devices can be incorporated to hold the reactor at any given state.

(*c*) Neutrons, fission products and radiation arising from fission processes are all highly injurious to human beings and indeed to many engineering materials, as well as all forms of living matter. It is necessary therefore to provide massive shielding, consisting usually of many feet of high density concrete between the operating staff and the reacting core, and to incorporate many safety devices to ensure that the special radiation and fission product hazards are either eliminated or kept fully under control.

(*d*) Finally some means must be provided of removing the heat from the reactor and converting it into useful work. The cooling medium must satisfy three conditions:

(i) It must not absorb too many neutrons, otherwise it will simply "put out" the pile.

(ii) It must not have chemical properties which would lead it to react unfavourably chemically with the other materials in the reactor. Complications arise here in that many chemical reactions are strongly influenced by the presence of nuclear radiation.

(iii) It must have engineering properties suitable to its role as a coolant.

One of the few suitable cooling mediums for a natural uranium reactor is carbon dioxide, and this, under pressure, is being used for the reactors at Calder Hall and Chapel Cross, and is one of the possibilities for the first C.E.A. reactors. No details have yet been released of what in fact will be used.

Calder Hall and Chapel Cross

Having discussed at some length the principles involved in the design of natural uranium, gas-cooled, graphite-moderated reactors we can now conveniently pass on to a consideration of the first major power-producing reactors of this type to be built in the country, and indeed in the world, those at Calder Hall and Chapel Cross. The fore-runners of these installations are the experimental natural uranium, graphite-moderated, air-cooled piles GLEEP and BEPO at Harwell and the similar large-scale piles at Windscale, which are used for the production of plutonium, though not of power. Calder Hall and Chapel Cross, however, though primarily intended for the production of plutonium, have, as a major secondary role, the production of electric power. This is a convenient point to discuss the relationship of these two roles.

As previously stated, when neutrons are absorbed by U238, the fertile component of natural uranium, the fissile element plutonium is formed. In a natural uranium reactor quite a substantial proportion of the neutrons are in fact absorbed in the U238 and therefore a significant amount of plutonium is produced. This process is not, however, a breeding process and the amount of plutonium produced is substantially less than the amount of U235 destroyed. The importance of the process lies in the fact that plutonium is an entirely different element from uranium, and therefore the small amounts of plutonium formed can be relatively easily separated out from the residual U238. This means that the plutonium can readily be obtained in the high concentrations needed for nuclear weapons. Thus the operation of a natural uranium reactor is an economic alternative to the highly complex vapour-diffusion process for the production of fissile materials for warlike ends.

In fact it had been the German intention during the last war to produce plutonium for nuclear weapons by operating a natural uranium heavy water-moderated reactor, and this was the reason for our attack on the heavy water plant in Norway, which would have been the source of what was then considered to be the only suitable material for a moderator in a reactor of this type.

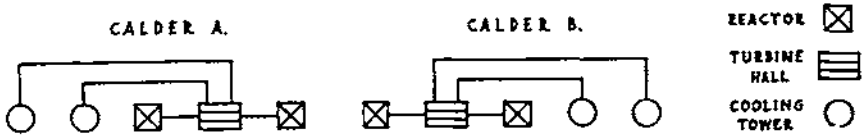
The main difference between the reactors at Calder Hall and the earlier ones at Windscale arises from the fact that the former are required to yield power as well as plutonium, while in the latter the power is allowed to run to waste. For thermal efficiency in the working medium, whatever it may be, a reactor must run at the highest possible temperature, whereas when there is no power requirement, the working temperature can be kept low. Thus at Windscale, and in the earlier experimental piles, the core temperature is low and cooling is carried out by air. Unfortunately at higher temperatures the graphite moderator, which after all is merely very pure carbon, would burn in air, and therefore a more inert gas has to be used. This leads to the choice of carbon dioxide as a coolant. Even then there is a limitation on temperature in that carbon dioxide and graphite tend to combine at high temperatures to form carbon monoxide. This tendency can be reduced by increasing the pressure of the carbon dioxide. Helium, because it is completely inert, would make a better coolant but is not economically available in this country.

The other main difficulty arising from attempts to raise the reactor temperature is that the uranium fuel elements start swelling and distorting, thus breaking out from the special cans in which they have to be confined, and releasing the highly radioactive and toxic fission products into the circulating system. In short the struggle to extract power from a reactor at a reasonable thermal efficiency becomes a highly complex exercise in chemical and metallurgical engineering, rather than a problem in nuclear physics. Incidentally the large chimneys at Windscale are merely the means by which the cooling air, which might possibly get slightly contaminated with fission products from a leaking fuel element, is discharged safely into the upper air. Calder Hall has no such requirement, and therefore no chimneys.

Basic Design of Calder Hall

The reader will no doubt have seen numerous accounts of the installation at Calder Hall. The basic facts of the design may be summarized as follows:

Two nuclear power stations are being constructed at Calder Hall. Each consists of two reactors, a central turbine house and two cooling towers, the two stations being arranged in line as in the sketch below.



Each reactor has a heat rating of 180 MW. and powers two 21 MW. steam turbo-alternators through four heat exchangers in which steam is generated by the heated carbon dioxide. Thus the electrical output from each reactor is 42 MW. and from each station 84 MW. A proportion of this is fed back to the station auxiliaries leaving about 70 MW. available for external use. Each reactor consists of a graphite cylinder 36 ft. in diameter and 27 ft. high weighing about 1,100 tons, inside a pressure vessel of 2-in. thick steel, 37 ft. in diameter and 71 ft. high. The reacting core consists of 63 tons of uranium. This is in the form of rods 40 in. long and 1·15 in. in diameter. These are placed six to a channel in 1,696 vertical channels in the graphite core. The carbon dioxide coolant is at a pressure of 100 p.s.i. and circulates at a rate of 7,000,000 lb. per hour. Around the pressure vessel is shielding consisting of 6 in. of steel and 7–8 ft. of concrete. The whole reactor structure including shielding weighs 33,000 tons, and is supported on a concrete raft 11 ft. thick.

The maximum permissible operating temperature in the core is about 400°C. This has led to a coolant outlet temperature of 336°C., the inlet temperature being 140°C. This in turn leads to the somewhat modest high-pressure steam conditions of 200 p.s.i. at 590°F., and the equally modest overall thermal efficiency of about 23 per cent.

Very full descriptions of the Calder Hall design have appeared in the technical and popular press, so it is not proposed to devote further space to it here. Sources of further information are listed in the bibliography at the end of this article.

The First C.E.A. Stations

Until the advent of the White Paper programme for electric power from nuclear energy all work in this field had been carried out either by or for the U.K. Atomic Energy Authority. It now became deliberate Government policy to widen enormously the range of mental and physical resources to be applied to the vast problems of nuclear engineering. It was therefore decided that the U.K.A.E.A. would simply be an advisory body for the new programme, and that the onus of designing and building the new stations would fall on the C.E.A. and civil industry. The main background of fundamental and applied research associated with the programme would still be carried out by the Atomic Energy Research Establishment at Harwell, but none the less there would be substantial contribution by private enterprise in this field as well. In order to muster sufficient resources a special atomic energy division of the C.E.A. was established and at the same time four major industrial groups were set up to prepare designs and tenders for the first stations. These groups were formed around four national electrical combines, the General Electric Company, the English Electric Company, C. A. Parsons, and the Associated Electrical Industries. A great effort was made at Harwell to train staff both for the C.E.A. and the contracting groups; the C.E.A., in conjunction with the A.E.A., produced broad specifications; and the contracting groups, also in conjunction with the A.E.A., produced detailed designs and competitive tenders. It can well be appreciated that in the peculiar circumstances involved, with all the knowledge of the subject being initially concentrated in the A.E.A., considerable complications arose over the problem of stimulating competition at the same time as co-operation, and of holding the balance between the clients, the C.E.A., and the contractors. However, it appears that the difficulties involved were overcome satisfactorily and the designs and tenders for the new stations were submitted to the C.E.A. last October, just at about the same time as Calder Hall started to feed current into the grid.

The differences between the first C.E.A. stations and Calder Hall are largely a matter of engineering development, though there will also be slight differences in that the new stations are being designed and operated primarily for the production of power and not for plutonium. Design details have not yet been released, but three main trends of development will probably emerge. Firstly, with improved welding techniques, the pressure vessel may be fabricated from plates 3 in. instead of 2 in. thick. This would allow a larger reactor to be built and higher gas pressures to be used. Secondly improvements in the design of the fuel elements might allow a higher maximum temperature in the reactor and hence higher steam temperatures and pressures. Thirdly designs may have been achieved that will allow the fuel elements to be changed without shutting down the reactor. This would allow continuous generation of electricity to take place, apart from normal brief shut downs for maintenance. As a result the electrical output of the stations may be between two and three times that of the Calder Hall stations and the thermal efficiency may be increased from 23 per cent to about 28 per cent. It appears therefore that the electrical output from the first stations may be about 200 MW. (from the pair of reactors) but it is hoped to raise this figure to somewhere near 300 MW. without any basic alteration in design. The White Paper programme, as already stated, was based on 150 MW. per station, so that it appears that technical development is going faster than was forecast.

Stage Two Reactors

The stage one reactors so far discussed burn natural uranium, or possibly at a slightly later stage, natural uranium that has been very slightly enriched to the extent of an extra 200 grams (8 oz.) of U235 per ton. However, the stage two reactors of the programme will depend on fuel that has been substantially enriched by the addition of extra fissile material in the form of plutonium, which, it will be recalled, will be accumulating as a by-product from the operation of the stage one reactors. The degree of enrichment might be equivalent to increasing the fissile content by 50 per cent or more, or by using reacting cores containing combinations of enriched and natural fuels. Fuel of this nature burns far more readily than natural uranium so that reactors can be smaller and far more latitude is permissible in design. The use of these enriched fuel reactors for commercial power production would be economic only when substantial quantities of surplus fissile material were available at reasonable costs, either as by-products from natural uranium reactors or as a surplus from military production plants. The main interest in these reactors at present, apart from long term development for commercial purposes, is in military fields, for the powering of submarines and other naval vessels, for the Army power packs and possibly for aircraft. This is being followed up in the commercial field by development for powering cargo ships, particularly tankers, and for small power plants for areas remote from normal fuel supplies. Many types of reactors fall into this category; three main ones are discussed below.

Pressurized Water Reactors (P.W.Rs.)

With enriched fuels the need for neutron economy is not so pressing and a wide range of materials can be used for moderators and coolants. Many possibilities are being examined, and many years will certainly go by before any finality is reached. One apparently simple solution, however, is the use of pressurized water both as moderator and coolant. This type of reactor is of particular interest in that it was chosen for the famous American nuclear-powered submarine, *Nautilus*, for the American Army Packaged Reactor (APPR-1), for the first Russian nuclear power station and for a full scale experimental power station now under construction at Shippingworth, U.S.A. It is also one of the basic types being considered for ship propulsion, and one of the candidates for stage two of the U.K. nuclear power programme.

It is convenient to start by considering the Shippingworth reactor. This is to be the first central-station nuclear power plant in U.S.A. and is one of which the details are fairly well known as a result of the Geneva Conference in 1955. To some extent this reactor can be said to occupy the same place in the American programme as Calder Hall does in ours. It is therefore of interest to compare the two. The heat output of the single reactor at Shippingworth will be about 260 MW. compared with the 180 MW. of each of the two reactors in the Calder Hall stations. The amount of fuel in the reacting core will be about a quarter of that in the Calder Hall reactors. A broad comparison between the two can be seen from the following table:—

	Calder Hall	*Shippingworth*
Heat output per reactor (mW.)	180	260
Tonnage of fuel	63	about 15
Core diameter (ft.)	36	6
Core height (ft.)	27	$7\frac{1}{2}$
Pressure vessel diameter (ft.)	37	9
Pressure vessel height (ft.)	71	28
Coolant pressure p.s.i.	100	2,000
Maximum coolant temperature (°C.)	336	283
Maximum uranium temperature (°C.)	400	320 (approx.)

Thus it can be seen that though a more compact type of reactor is obtained on the pressurized water design, operating temperatures are relatively low, the limit being set by the engineering difficulties of working above 2,000 p.s.i. water pressure. This pressure limit is in effect a temperature limit due to the necessity for avoiding steam formation anywhere in the pile. Another main difficulty in this design is that hot water in the presence of radiation is particularly corrosive. Fuel elements, therefore, have to be sheathed in special and very expensive zirconium alloys. In general the results at present are that reactors of this type have a relatively low capital cost, largely because of their smaller size, but have a high fuel cost due both to the enriching process and the special canning of the uranium rods.

Graphite-Moderated Sodium-Cooled Reactors

The second main runner in the stage two stakes of the U.K. programme is the graphite moderated sodium-cooled reactor using enriched uranium. The main advantages of this over the P.W.R. type discussed above is that the pressure of the liquid sodium would be low and therefore simpler designs and larger sizes are possible. Reactors of 1,200 MW. heat output are envisaged. Also sodium is compatible with uranium and would not attack it in the event of a leak. On the other hand sodium attacks graphite, so the graphite would have to be canned. Other disadvantages are that there is a great hazard if any water comes into contact with the sodium in the heat exchangers; and as sodium tends to absorb neutrons the general neutron economy is poor, leading to a poor conversion of U238 to plutonium. At present a great deal of work on this type of reactor is going on at Harwell, and definite evaluations should be obtained in about a year.

Reactors Moderated and Cooled by Organic Liquids

These may be regarded as the dark horses of the stage two stakes. Organic compounds consisting largely of hydrogen and carbon are as good moderators as water, though not so good as graphite. In addition many have high boiling points so that they can be used at much lower pressures than would be needed with water, possibly 200 p.s.i. instead of 2,000 p.s.i. They are also much less corrosive than water, but unfortunately tend to be unstable in the presence of radiation. Diphenyl, ferphenyl and a number of silicones have been considered, and the Americans have got as far as doing reactor experiments in this field and constructing a small reactor of this type for one of the South American states.

Stage Three Reactors

Having considered the three main lines of approach to the stage two reactor designs, and remembering that not only are there many variations within the types, but that there are many other less favoured types as well, it is time to pass on to a discussion of the third stage of the White Paper programme. This may be called the breeding reactor stage, i.e., the stage of reactors that produce more fuel than they consume. A number of approaches to the design of such reactors is possible.

(a) *The Fast Breeder Reactor.* This is called "fast" because no moderator is used and therefore the neutrons all travel at the high speeds at which they are emitted from the fission process. A very highly enriched fuel is used, the core consisting perhaps of 500 kg. of plutonium and 1,000 kg. of

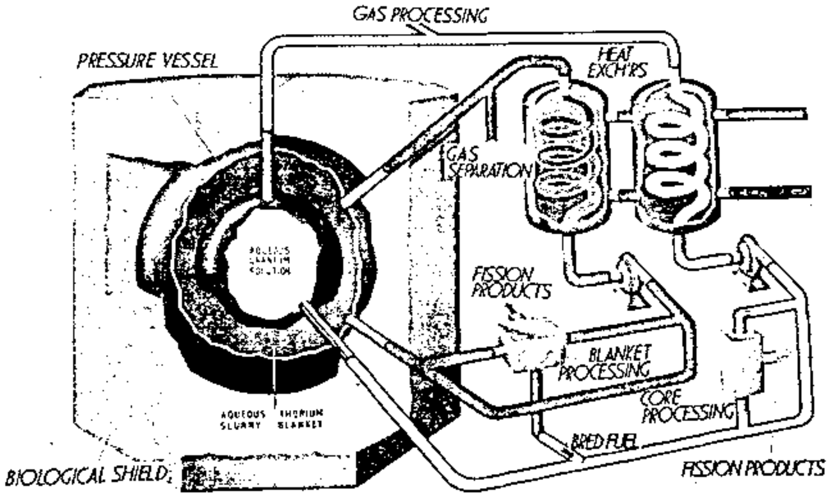


Fig. 5.—Diagram of aqueous homogeneous reactor, showing general arrangement for continuous removal of fission products and continuous processing of blanket to remove bred fuel.

U238, the whole being surrounded by a blanket of U238 in which the main breeding process takes place with the production of more plutonium. Experiments with the reactor ZEPHYR at Harwell have shown that in these conditions 1·7 atoms of plutonium would be formed for every atom destroyed. The initial charges for the stage three stations would come slowly from the plutonium produced in the stage one stations, but once the stage three stations really got going there would be a steady build-up of fuel. However, there are many difficulties to be overcome before these dreams can be realized. The main difficulties are the engineering ones of cooling such an intensely concentrated power source, about one fiftieth of the size of that at Calder Hall; and a great field of chemical and metallurgical difficulties, which are primarily a matter of cost, involved in the separation out of the plutonium and its refabrication into fuel rods. In view of the importance of this type of reactor a full-scale experimental power reactor is being built in this country at Dounreay on the north coast of Scotland. Other reactors of this type have been, or are being built, in the U.S.A. The Dounreay reactor is described further below.

(*b*) *Thermal Breeder Reactors.* Two types are being studied, both working on the uranium233/thorium cycle, both using liquid fuels to reduce the cost of fabricating and re-fabricating fuel rods, and both, as the term "thermal" implies, incorporating moderators.

(i) *Aqueous Homogeneous Reactors.* The reacting core consists of a solution of uranium233 sulphate in heavy water and the blanket is a thorium slurry. The heavy water acts as a moderator, and heat removal is effected by the circulation of the reacting solution.

(ii) *Liquid Metal Fuel Reactors.* These might consist of a solution of uranium in liquid bismuth circulating through a graphite moderator, with the reacting area surrounded by a blanket of thorium.

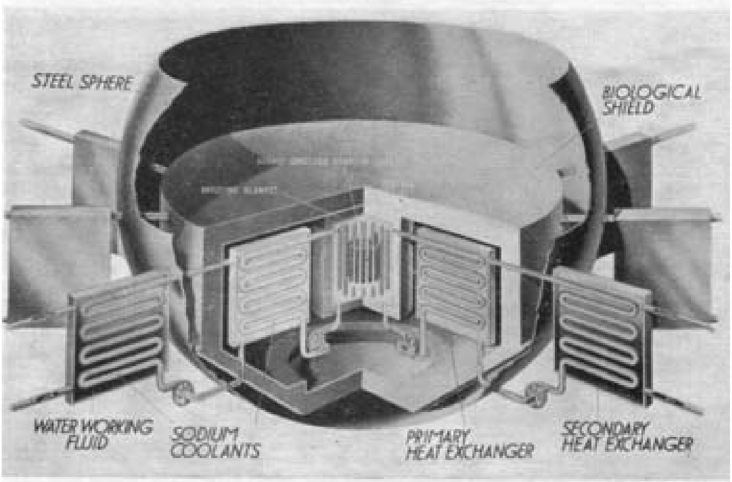


Fig.—4. Diagram of fast fission breeder reactor at Dounreay cooled by liquid sodium.

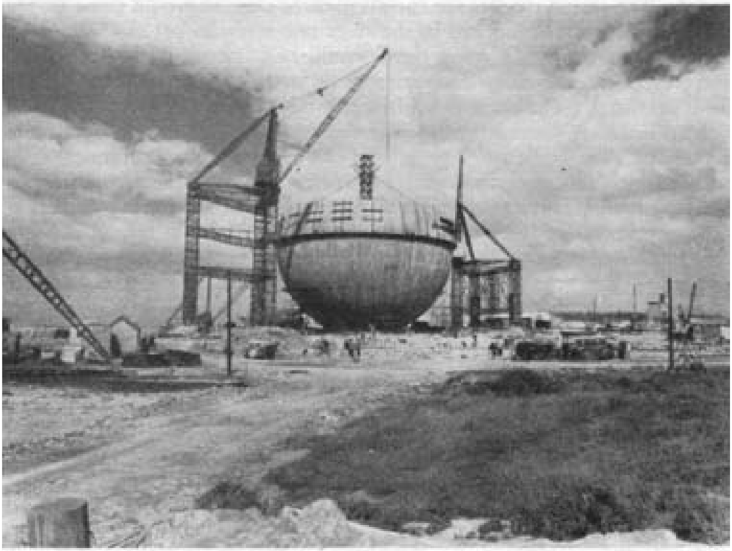


Fig. 5.—Container for Dounreay reactor under construction.

Nuclear Power Engineering 4 , 5

The main advantage in principle in these liquid fuel reactors is that they allow the planning of continuous operating cycles, with fresh fuel being added and fission products removed as part of the process. No major experimental reactors of the thermal breeder types are being constructed in this country at present.

Dounreay

Dounreay, as a large scale experimental version of the most promising type of stage three reactor, is one of the most fascinating engineering ventures in this country today. Imagine a dustbin 2 ft. in diameter and 2 ft. high, full of metallic rods an inch or so in diameter, neatly packed so that when the lid is removed the ends of the rods are visible. Half the rods, dark as wrought iron, are uranium, the other half, glistening golden, are plutonium canned in gold, because gold is stable and cheap. The whole, delicately balanced, is ready to start off, and as a few more rods are lowered into the half a dozen holes left for them the reaction starts and energy begins to flow in a limitless stream. To carry it away molten sodium pours in a surging torrent through channels in the dustbin until at last a balance is reached with a steady 60 MW. pouring out from our small and utterly simple container. What if the coolant stops? It must not stop. At Dounreay twenty separate coolant circuits will operate, the pumping power being provided from ten separate generators each operating only two pumps.

It must be emphasized that Dounreay is an experimental reactor, not a prototype. It is needed to investigate the many problems that must be solved before even a prototype can be made. There is an element of danger in it, and that is why it is sited in the extreme corner of Scotland, and enclosed in a steel sphere 155 ft. in diameter and sufficient to contain the products of any foreseeable mishap. It will take until 1960 to gain experience at Dounreay; a prototype might be ready by 1965, and the production reactors of this type might start coming into service in 1970.

Small Reactors

In the U.K. nuclear power programme considerations of size are not particularly important, and in fact the whole tendency is to build the largest possible reactors of any particular type that turns out to be commercially acceptable. However, in many other applications small size is of prime importance, and it is perhaps an unfortunate feature of nuclear engineering that the construction of reasonably efficient small nuclear power plants is relatively a great deal more difficult than that of large ones. As a result nuclear power in small quantities is likely to be expensive, and this of course limits the uses to which it will be put. The more promising fields are discussed below.

As nuclear power plants require neither fuel, in the conventional sense, nor air, they are a most attractive proposition for the propulsion of submarines. Cost in this case is a secondary factor, whereas the ability to travel submerged at full power almost indefinitely is all important. It is not surprising therefore that the first full scale power reactor was probably the prototype Submarine Thermal Reactor (STR). This started to generate electricity in June 1953, and was the forerunner of the power plant of the U.S. Submarine *Nautilus* that started its sea trials in January 1955. Very few details of this plant are available, except that the reactor uses highly enriched uranium235, and is of the pressurized-water type working at 1,500 p.s.i. The maximum core temperature would be about 300°C. giving rather inefficient steam conditions. The *Nautilus* has fully demonstrated the feasibility of nuclear-powered submarines and has successfully travelled submerged for thousands of miles at full speed. The latest venture by the Americans in this field is the *Sea Wolf*, powered by a sodium-cooled reactor, which would, at least theoretically, be far more compact and efficient than that of the *Nautilus*. However, it appears that there is trouble over the sodium cooling system, and the *Sea Wolf* cannot yet be counted a success. Two interesting articles on American developments in military fields are referred to in items 10 and 11 of the bibliography at the end of this paper.

Similar development work is proceeding in this country, though rather behind the Americans. From nuclear-powered submarines to surface warships is a short step, but difficulties arise on financial grounds as soon as an attempt is made to extend nuclear power to merchant shipping. None the less all the leading maritime countries are studying this problem, and the Americans may have two nuclear-powered merchant ships afloat within the next four years. The British Shipbuilding Research Council has a special team at Harwell. One of the least unfavourable fields is the application of nuclear power to tankers in the 30,000 ton deadweight class, but even here development has some way to go before commercially economic designs can be produced.

The main hope in this direction is that sufficient plutonium may be available, from military plants or as by-products of the stage one reactors of the power programme, to bring down substantially the price of pure fissile materials by about 1964. There is little doubt that suitable reactors, either of the pressurized-water, or the organic-liquid types will be available by that date, so that progress in this field will be more a matter of economics than of engineering.

The Americans have spent over $200,000,000 on reactors for aircraft and have got as far as taking a reactor up in an aeroplane, but they have not yet powered an aircraft by one. The main difficulty is the weight of the shielding. Using highly enriched, if not pure fissile material, on a fast reactor principle, the core size of an aircraft reactor might be within a 3-ft. diameter sphere. All round shielding for such a core would weigh 500,000 lb.; the all up weight of the largest aicraft at present is 400,000 lb. However, by having the reactor at the centre of gravity of the aircraft and the crew forward of it, a certain amount of selective shielding could be adopted, bringing the weight down to about 100,000 lb. The Comet weighs 153,000 lb. and carries 70,000 lb. of fuel so that reactor power is by no means impossible. To give an idea of the reactor ratings needed, the Comet IV requires 40 MW. of heat when cruising and large aircraft at supersonic speeds would require 200 MW. rising to 800 MW. as they developed.

The fundamental objection, however, to nuclear-powered aircraft, and a somewhat lesser objection to nuclear-powered ships, is the risk of accident. Sooner or later most aircraft crash, and immense damage would follow from the release of radiation from the reactor of a crashed aircraft. Considering both the costs involved and the risk, it is clear that there is little future for nuclear-powered aircraft except as part of an immensely powerful global bomber force. With ships there would be far less risk of an accidental release of radiation, but none the less the risk would always be present, and stringent precautions would have to be taken if the world's waterways became crowded with reactor driven craft of every kind.

Reactors for Military Power Plant

The one advantage of a reactor for military power plants is its negligible fuel consumption. Against this must be set, at least at present, its high capital cost, its great weight, its complexity, the serious construction effort involved in building it, and the fact that it cannot be dismantled for moving once operation has rendered it radio active. Bearing in mind these characteristics the following circumstances suggest themselves as being favourable to the use of reactor-powered plant:—

(*a*) Power generation for some remote, possibly Arctic, base, or smaller installation such as a radar station, where considerable cost and effort is involved in the supply of petroleum fuel. Owing to its low thermal efficiency a reactor power plant has a great deal of low grade waste heat. This might well be used for space heating in the Arctic, or for water distillation if the base were in an area which was short of fresh water.

(*b*) Use in a floating power station which could be moved by sea for port rehabilitation.

With these ends in view, which are stated more fully in the *Military Engineer* for March-April, 1955, the United States Corps of Engineers has sponsored the construction of a 10 MW. heat-output, packaged, power-reactor, APPR-1. This has been designed by the Oak Ridge National Laboratory on behalf of the U.S. Atomic Energy Commission and is being constructed at Fort Belvoir by the American Locomotive Company. The reactor is of the pressurized-water type, burning enriched uranium. Its operating pressure is 1,200 p.s.i. The maximum coolant temperature is 450°F. and steam is generated at 407°F. and 200 p.s.i. The reactor is designed to be air-portable in pieces not exceeding 9 × 9 × 27 ft. in size and 10 tons in weight. The total weight of the complete plant, however, has been stated to be 1,300 tons and its total size is estimated to be 80 ft. long, 29 ft. wide and 42 ft. high. The weight of 1,300 tons includes 900 tons for concrete shielding, and it has been stated recently that this will be reduced for remote sites by using an alternative shield of steel filled with water. These are formidable weights and dimensions for an equipment which will generate only 1,800 kW. of power, even if it does this without any fuel supply problem. The corresponding weights for diesel and gas turbine equipments based on six self-contained fully transportable 300-kW. generating sets would be 144 tons for the diesel sets and 30 tons for the gas turbine sets. The fuel consumption of these sets at full load would be about 0·3 ton/hr. for the diesels and 0.8 ton/hr. for the gas turbines. It is clear therefore that there would be an overall saving of tonnage in a matter of months, but that considerable initial expense and effort would be required to achieve this.

The APPR-1 is scheduled to complete its 700-hr. performance test in July of this year. This will of course be a matter of great interest, but it is hard to see any justification for the development of such an equipment for the British Army.

However, steady development is taking place in the small reactor field, and it has been forecast that sufficiently economic equipments will be available by 1965 to allow a steady export trade in such reactors from this country for use in less developed parts of the world where fuel costs are high. These reactors might be of the organic liquid-moderated type, and as such be simpler and cheaper than those depending on pressurized water. Also where cost is not the prime consideration, small, but powerful, reactors of the types being developed for aircraft and submarines may well be adaptable for military use on land. However, at present, it does not appear that, for the British Army at least, reactor-powered generating plant has any military characteristics that would justify spending on it any great proportion of the limited funds available for the development of engineer equipment. When more is known about smaller equipments, and when commercial models start coming into service, perhaps in five or six years' time, the situation may well be different. None the less it is essential that the subject should be kept under continuous review in case any new development materializes.

The Hazards of Nuclear Engineering

The peculiar hazards of nuclear engineering lie in the lethality of the radiation from the various products of nuclear reactions. The danger lies partly in the absorption of radiation transmitted from a distance, and partly in the risk of swallowing, breathing in, or otherwise coming into contact with radioactive particles. Protection against these hazards lies in the knowledge of the risk, in the continuous use of electronic or photographic instruments that can record the presence of radiation, in a high standard of design of the plant, in high standards of workmanship and inspection, and in the general integrity of the operating staff. When these conditions are satisfied the occupational risk involved in nuclear engineering is inherently smaller than that of many other engineering activities.

It is well known, however, that there have been two accidents with early experimental reactors in U.S.A. and one at Chalk River in Canada. These, however, were in the early stages of development, and there seems no reason why any serious accidents should arise with new experimental or power reactors. None the less, where radioactivity is present there must always be some risk of a small discharge, possibly for example through the fracturing of a fuel element.

Many comparable risks exist in other industries at present, mainly in the chemical engineering fields and in all such cases there are codes of practice to ensure that the consequences of any risk are kept to an absolute minimum. Absolute security from mishap cannot be obtained in any sphere of life.

Amongst methods of reducing the risks that might arise from an accident are the following:

(*a*) The enclosure of reactors in pressure vessels capable of containing the products of any foreseeable mishap.

(*b*) Building only inherently stable reactors, except in remote areas.

(*c*) Building no high-power reactors in populated areas until ample operating experience has been obtained.

(*d*) Incorporating every possible safety device in the design of reactors.

As a result it can be said that the implementation of the White Paper programme will introduce into this country nothing undue in the way of occupational or general hazards.

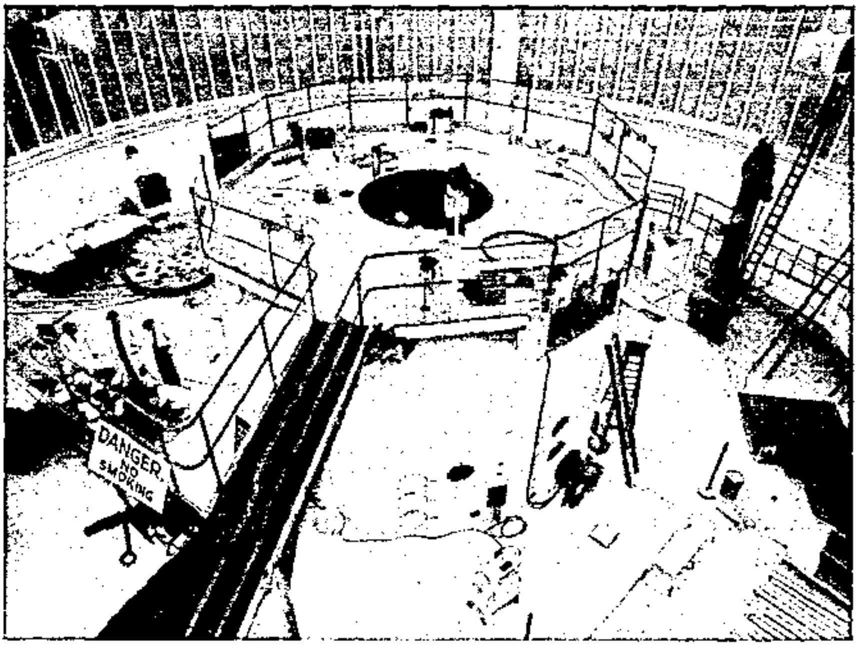


Fig. 6.—Experimental reactor DIDO, which came into action at Harwell during November, 1956. Fuel is highly enriched Uranium, moderator is heavy water. DIDO is the most powerful experimental reactor in Western Europe.

Some Trends of Development

Nuclear engineering development is proceeding at great speed in every major industrial country in the world; primarily of course in the U.S.A., U.S.S.R., and U.K. Much of this development is shrouded in secrecy, so that any attempt to state the facts runs the risk of being discredited almost immediately, either by new discoveries or by the release of information previously withheld. None the less it is of interest to mention here some of the main trends that are clearly visible in this enormous engineering field.

Increase in operating temperatures. This is one of the fundamental requirements for the economic production of power. Improved design of fuel elements of current types can play a small part, but the really important step in this direction may come with the successful development of ceramic elements, in which the uranium is combined with graphite as a carbide. With such elements it will be possible to operate a gas-cooled reactor at temperatures of 800°C., and to take the power from the gas direct through a gas turbine, thus completely eliminating all the steam-raising equipment of current types of plant. Fuel elements of this type have already been tested in BEPO, the original graphite-moderated pile at Harwell, and may already have been tested in DIDO, the new 10 MW. enriched uranium, heavy-water-moderated and cooled test reactor recently completed at Harwell.

Coolants. Much work is proceeding on the study of coolants, particularly the liquid metal coolants, such as sodium, which are likely to be used for the more highly rated reactors. Work of this type will be carried out at Harwell in the new experimental reactor PLUTO, which is somewhat similar to DIDO.

Materials. An enormous amount of work is needed to establish the engineering properties in high-intensity radiation fields of the wide range of common as well as exotic materials which are being pressed into the service of the nuclear engineer.

Metallurgy of Plutonium. This artificial metal is proving to have most complex and highly undesirable metallurgical properties. A very great effort is needed to overcome the difficulties arising in this field.

Shielding. This is one of the more difficult and expensive aspects of nuclear engineering, particularly in relation to small mobile reactors. It is being specially studied at Harwell in LIDO, a "swimming pool" reactor, consisting essentially of a mass of enriched uranium which can be lowered into and moved about in a pool of water. There is no reaction when the uranium is out of the water, but as soon as it is lowered into it, the water acts as a moderator and the reaction starts. At the same time there is enough water to act as a coolant, so the reacting mass does not get particularly hot. The uranium can be moved in the water up to different samples of shielding so that their effectiveness can be determined.

Recycling. The economics of nuclear fuel depends very much on the methods and cost of extracting and re-using the plutonium formed in any reactor. This, of course, will be particularly important when the breeder reactor stage is reached. This subject is covered by the general term recycling. The main complication in re-cycling lies in the intensely radioactive nature of the materials being handled and the necessity, therefore, to handle them all by methods involving remote control.

Reactor Types. A great deal of work is going on in connexion with the study of reactor types as discussed earlier in this paper. This is often carried out in so-called zero energy reactors, i.e., reactors which are so controlled that they work only at a zero energy level. Thus ZEUS, the prototype at Harwell of the 60 MW. Dounreay reactor, is operated at only 4 W.

Controlled Thermo-nuclear Reactor. Work has been going on at Harwell since 1948 on the possibilities of obtaining economic power from controlled thermo-nuclear reactions, i.e., by fusion processes as opposed to fission. Two main problems must be solved; to bring a mixture of the two heavy isotopes of hydrogen, deuterium and tritium, to a temperature 100,000,000° C. and to maintain this temperature long enough for the energy released in fusion to be greater than that required to heat the fuel. This work is still in a laboratory stage, but holds out visions of limitless power for the future.

Conclusion

Having reached so far the reader will realize that this article is but the briefest survey in skeleton form of an enormous province of modern engineering thought and action. It does, however, form a reasonably coherent basis for thought and further study, and is an attempt to give a broad and balanced view of a subject that tends at times to disappear from the average engineer in a mist of novel conceptions, strange terminology, and unfamiliar technicalities.

Condensation of this type results inevitably in the elimination of only too many of the finer shades of argument and proviso needed to balance the facts and conclusions somewhat baldly stated in such limited space. Those who know more of the subject than the average reader may well be tempted to bemoan a presentation where the subject has been reduced to its bare bones, with little meat around them. They must console themselves with the thought that the study of anatomy must start with the skeleton and that the meat nearest the bone is often the most sweet.

Brief Bibliography

1. *An Introduction to Reactor Physics* by D. J. Littler, the head of the Reactor School at Harwell, and J. F. Raffle. Published by the Pergamon Press for the U.K.A.E.A. 1955.

2. *Principles of Nuclear Reactor Engineering* by Samuel Glasstone, published under authority of the U.S. Atomic Energy Commission U.K. edition by Macmillan and Co. Ltd. 1956.

3. *Peaceful Uses of Atomic Energy.* Proceedings of the 1955 Geneva Conference published in sixteen volumes by the United Nations, particularly Volume 3 "Power Reactors".

4. *Possibilities of Action in the Field of Nuclear Energy* published by the Organization for European Economic Co-operation, January, 1956.

5. *A Programme of Nuclear Power.* Cmd. 9389, February, 1955.

6. *The Hazards to Man of Nuclear and Allied Radiations.* Cmd. 9780, June, 1956.

7. *United Kingdom Atomic Energy Authority Second Annual Report,* 1955–6.

8. "ORNL's Design for a Power Reactor Package", *Nucleonics,* May, 1955.

9. *Nuclear Engineering,* (Calder Hall number), October, 1956.

10. "Military Nuclear Power", William B. Taylor. *The Military Engineer,* March–April 1955.

11. "Practical Utilization of Atomic Power", J. D. Anderson. *The Military Engineer,* July–August, 1956.

12. *Atomic Energy—A Financial Times Survey.* 9th April, 1956.

I would like to record my thanks to Doctor D. J. Littler, Principal of the Reactor School at Harwell, and to other members of the Harwell staff who have read and commented on this paper and also to the P.R.O. staff of the U.K.A.E.A., who went to much trouble to produce the illustrations.

The History and Development of the Bucket Excavator

By Captain P. A. Camp, R.E.

I wonder how many of us, laymen and engineers alike, realize that the gigantic excavators we so often see at work on large excavation projects originated in principle over 400 years ago, and are the outcome of intense development over the last 100 years. The earliest mechanical shovel, or navvy, to use the more familiar modern term, was designed by Leonardo da Vinci in 1513. It was designed for underwater digging and was built on a pontoon. Whether the machine was actually ever used we do not know, but the principle was used in the designs of the machines nearly 300 years later.

The nineteenth century heralded an era of large public works projects throughout the civilized countries of the world. In America, the United Kingdom and Russia, the development and expansion of rail and canal communications necessitated earth excavation on an enormous scale, which only some form of a mechanical digger could tackle.

Development of the Mechanical Shovel

The first power shovel was constructed in 1837. It was designed and patented by an American, William Otis, and built by the firm of Eastwick and Harrison of Philadelphia. The machine was of wrought iron and timber construction. It consisted of a bucket and dipper stick sliding on a hoist boom, and free to swing through 180 deg. about a vertical mast. Power was supplied by a single-cylinder vertical steam engine. The hoisting and digging actions were affected by chains working off winch drums, and the swinging action by means of a chain-driven turntable, mounted on a vertical boom, and connected to the hoist boom by two tag chains. The whole machine was mounted on four wheels, and ran on timber packing. The hoist and digging action was, in fact, almost identical to that of the present-day face shovel, the chains having been replaced by steel-wire ropes.

The first Otis shovel had an active working life of sixty-eight years. It began work on the Maryland Railway, and was then transhipped to Canada for canal excavation, and later mounted on a pontoon and used as a dredge. It finally came to grief in 1905. It is of note to mention that the second and third Otis shovels constructed were ordered by Russia for her public works projects, and the fourth by England for excavation work on the Eastern Counties Railway, and it started work in 1840.

A shovel almost identical in design to the Otis was put into production by a former employer of William Otis, Mr. John Souter, who named his machine "The Boston Shovel". Several of these machines were constructed in the following years with little modification to the original design. Bucket capacities of these machines varied between 1¼ and 2½ cu. yds. In 1852, one of the present-day leading excavator manufacturers introduced their first machine. This was the firm of Jason C. Osgood, to whom the advent of the dragline is attributed.

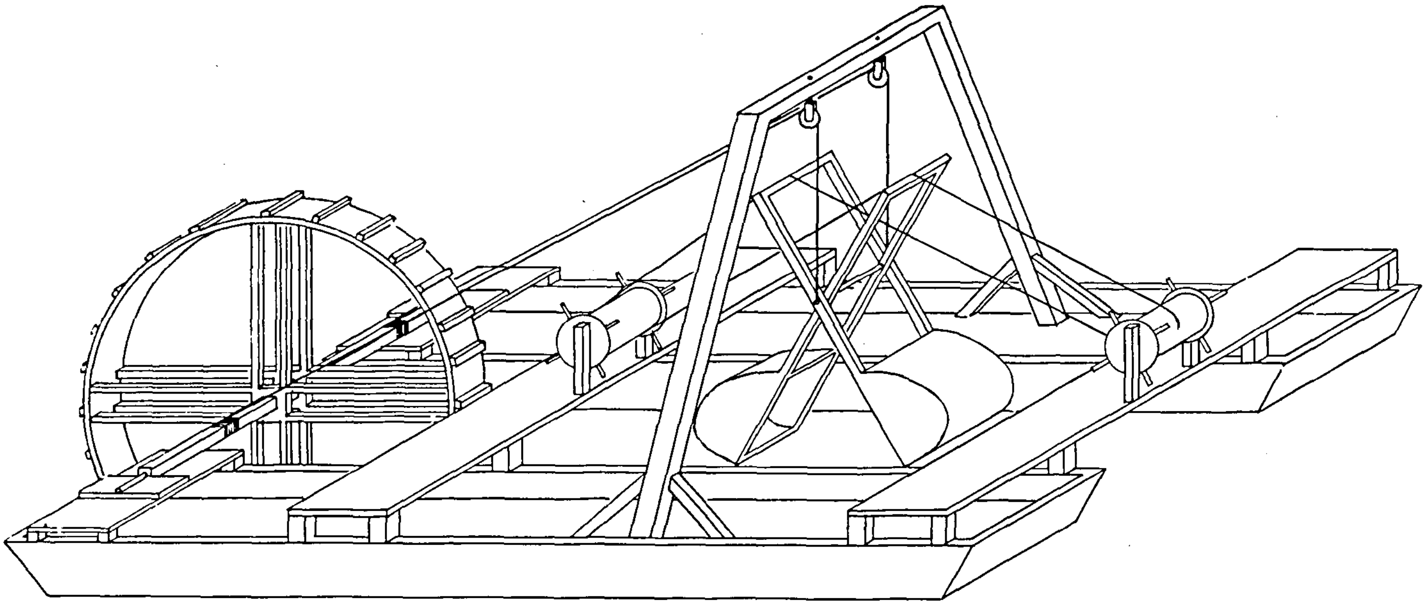


Fig. 1.—The design of Leonardo da Vinci, 1513.

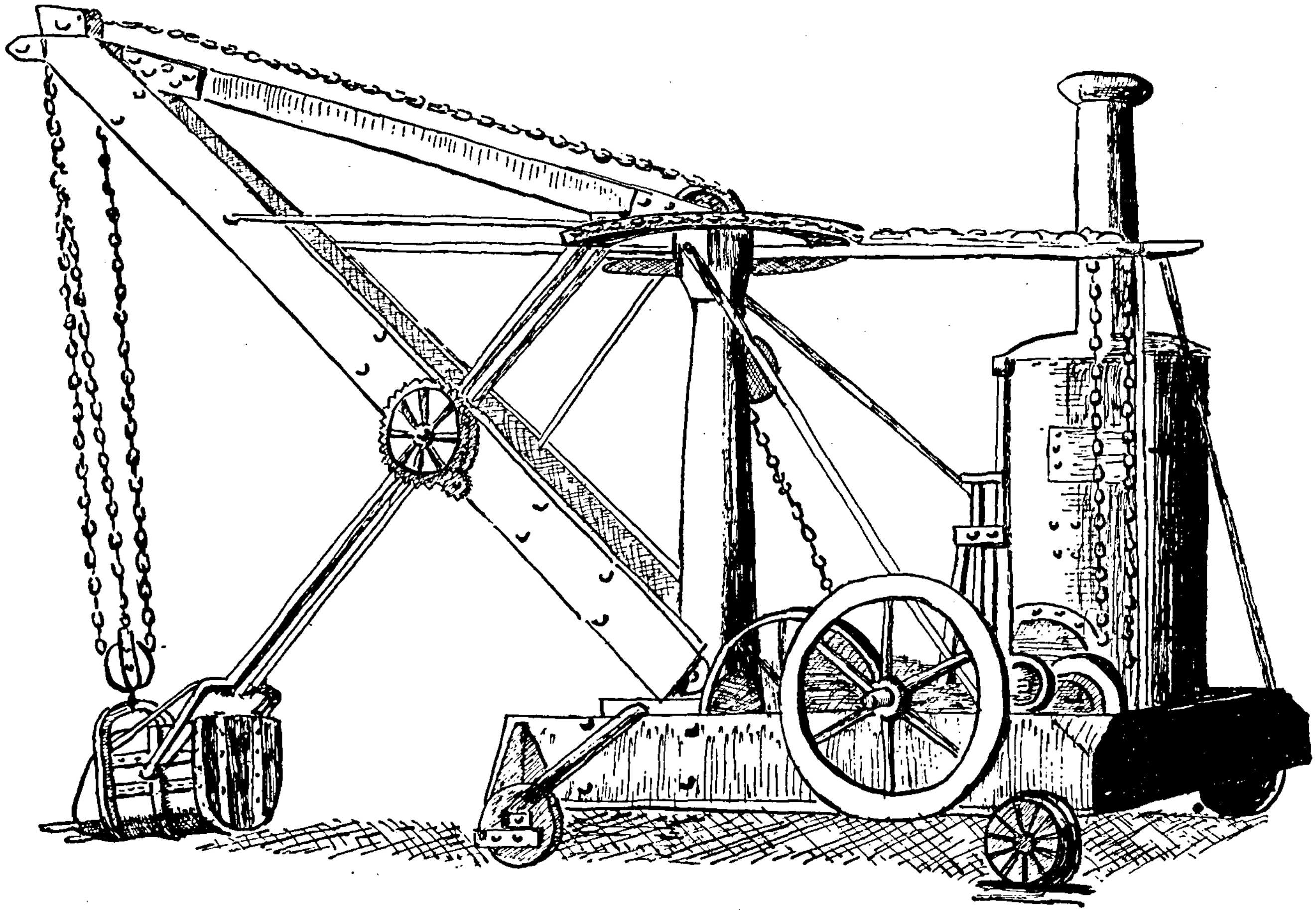


Fig. 2.—"The Otis Shovel", 1837, the first power shovel.

Following very closely on the lead of the Americans, the English firm of Messrs. Ruston and Proctor Co., Ltd., of Lincoln, began the construction of their first mechanical excavator. Their design was based on a patent of James Dunbar, a Scotsman, who was alive to the obvious advantages of mechanical excavators applied to the rail and canal projects being carried out at that time. The first Ruston machine was constructed in 1831, and unlike its American predecessors, was of an all wrought iron construction. A great number of these machines were constructed, and over seventy were used in the construction of the Manchester Ship Canal.

The main disadvantage of the early shovels was their inability to swing more than 180 deg., and although the designers were aware of the disadvantages of such a limited arc, it was not until 1884 that the first 360 deg. swing machines were constructed.

It was in this year that the English firm of Whittaker & Sons, of Leeds, adapted a locomotive crane as a mechanical shovel. This machine was able to traverse through 360 deg. and, like the present day counterparts, had all machinery, including the boom and its power unit, mounted on a revolving frame. The machinery was free to revolve about a pivot on a bottom frame carrying the travelling devices. Whittakers named their machine "The Jubilee Crane Navvy", having been introduced in the Jubilee Year of Queen Victoria. This machine was followed by another Ruston patent in 1902, which was mounted on rails, and was self mobile. It could also traverse through 360 deg., and was the first shovel having all the characteristic movements of the present day machines, i.e., travelling, hoisting, crowding.

At about the turn of the century, dragline buckets were beginning to be constructed and used. They consisted of a rectangular-shaped skip, suspended from the crane boom and having a dragrope reeved to a separate winch. The action of the dragrope being to pull the skip towards the base machine and fill it. The dragline was particularly easy to adapt to the two-drum hoisting engine used by most contractors at that time, and consequently was a very popular machine.

All these machines were powered by steam engines, but already the possibility of using electricity was being explored, and in fact the first electrical excavator was manufactured by Bucyrus Co., in 1894. Osgoods and Rustons soon followed this lead, and the latter firm constructed a single D.C. motor shovel for open-cast mining in Spain, as early as 1902. The tendency was to use electrical power units in the larger mechanical excavators. Various systems were developed, but the most successful was the Ward-Leonard system. The principle of this system is to supply a variable voltage current to a motor by means of an associated generator. The voltage of the generator is controlled by variation of its excitation, and the speed of the motor is controlled by varying the applied voltage. Each motion of the machine is powered by a separate motor, i.e., for hoisting, crowding, travelling and swing, and each motor is driven by a D.C. generator which derives its power from the main induction motor, supplied by electricity from outside sources. This system is in use today on the larger machines of bucket capacity of 30–45 cu. yds.

The opening of large open-cast iron ore sites in the U.S.A. and excavation of the Panama Canal created a need at the beginning of the century for larger and more powerful shovels than had previously been constructed. The open-cast sites required long boom shovels to remove and dump overburden. The forerunner of these long-boomed large capacity machines was built in 1900 by the firm of John Wilson of Liverpool. It was a 70-ton machine with a 70-ft. boom and 1½ cu. yds. bucket. The boom and dipper stick were of a lattice construction, and the racking gear was operated by a steam cylinder. The base frame had outriggers and jacks incorporated in it for stability. It was manufactured for the founders of Messrs. Stewarts and Lloyds, the company which now owns the world's largest walking dragline. In 1902 Lloyds reconstructed the machine, replacing the frame with a heavier one to dispense with the necessity of using jacks and outriggers, and incorporating replaceable bucket teeth for the first time. The machine was still in use as late as 1948 at Corby, Northants.

The Introduction of Crawler Tracks and the Oil Engine

All the machines which have been described so far, were mounted on rail wheels and were very limited in manœuvrability at the excavation face. Clearly, some other travelling means were necessary and the designers turned towards the use of crawler tracks. Development in this field began as early as 1908, and the first track-laying mechanical excavator was constructed in 1911 by Bucyrus & Co.

The tracks used on this machine consisted of steel-shod timber blocks fixed to cast-steel links formed into an endless chain. The construction of the links was such that it left large gaps, a feature which led to continual breakdown. Large rocks and stones would find their way into the links causing them to break only too frequently. Modern tracks have overcome this original fault by incorporating chain links, and steel pads have replaced the steel-shod blocks. Originally, steering of the tracks was controlled by an operator on the ground by means of dog clutches, but within a few years control was effected from the cab by means of friction and dog clutches.

Although electricity was used to drive the larger machines, the smaller machines still continued to be driven by steam until as late as 1912 when the first change-over to petrol and oil engines began. From the outset the petrol engine was not particularly successful. It was unreliable, there were frequent breakdowns, and the high cost of petrol, even in those times, persuaded the designers to favour the compression ignition engine. The development of the C.I. engine reached its peak in the years 1922–5, when many manufacturers of mechanical shovels simultaneously adopted its use. These engines were slow running, at approx. 350 r.p.m., and were of the three- and four-cylinder type. Their main trouble was due to an exposed valve gear, open to the detrimental effects of dust at the working site. They were heavy in maintenance costs and very prone to excessive wear. The present successor to these engines is the two- and four-cycle diesel engine running at 1,200–1,500 r.p.m. and completely enclosed. Diesel engines are now generally confined to the smaller machines up to 3½ cu. yds. capacity. From the outset, compressed air starting has remained most popular and is used on all combustion engines driving mechanical shovels, with the exception of those below ¾ cu. yd. capacity, which usually incorporate an electrical starting device.

One of the major problems which confronted early designers was the method of transmitting power to the various motions smoothly and efficiently. The earlier models incorporated gears and cone clutches lined with hard-wood to effect this purpose, the others had separate engines for each motion. In the following years more efficient and robust systems were developed and modern machines now use either the plate or the internal and external expanding band type clutches.

Digging Equipment—The Face Shovel

Until 1912, the majority of mechanical excavators constructed were fitted with face shovel equipment. This type of equipment consists of a bucket attached to a dipper stick, supported about a pivot on a main hoist boom. Digging is achieved by an upwards and outwards thrusting movement of the bucket against a quarry face which is above the level of the base of the machine. On the earlier machines the outward thrust of the dipper stick was achieved by hand operation. A large wheel, turned by an operator standing on the platform, moved rack pinions which in turn engaged with a racking gear on the dipper stick. The upward movement of the bucket was achieved by a hoisting chain reeved over a pulley in the boom-head to a steam-driven winch on the platform. This type of machine often caused injury to the "wheel" operator, who was frequently pitched off his platform by a backward thrust of the dipper stick caused by a rock movement in the upward digging action. The difficulty was finally overcome by the introduction of power operated racking devices. The most successful was the use of reversible crowd engines mounted on the boom, which drove the rack in and out as the operator wished. This method is still used on the few steam navvies manufactured today.

A simpler version of the face shovel was the Luffing boom type. In this case the dipper stick was pivoted at one end to the main boom. The upward action of the bucket remained unchanged. There was no positive crowd or thrust action, and digging was achieved by hoisting or lowering the boom to adjust the depth of cut. The advantages of the Luffing boom shovel were simplicity and low manufacturing cost.

A later development, appearing in 1926, was the chain-driven crowd in which a roller chain took the drive to a pair of reversing clutches mounted on the boom, thence through a bevel reduction gear to the racking arm. Modern chain-driven crowds have a chain taking the drive direct from the main machinery to the racking shaft, the crowd retract action being actuated by a planetary gear system and band-type clutches.

The rope crowd, which in its various forms is used on many present-day small shovels, made its first appearance about 1910. This early type had ropes attached to either end of the dipper stick and operated by a reversing steam engine. Its modern counterpart works in a very similar manner with various types of clutches replacing the reversing steam engine to effect the crowd and retract action.

Dragline

Although towards the end of the eighteenth century, a type of dragline had been patented and produced by Osgood & Co., it was not until after the 1914–18 war that the usefulness of this rig in excavating below track level was fully appreciated. The dragline is a particularly adaptable front-end equipment, the universal boom allowing the machine to be rigged as a clam-shell, grab, crane or pile-driver. However, its greatest asset as an excavating tool is its very long reach. The original booms were constructed from rolled steel

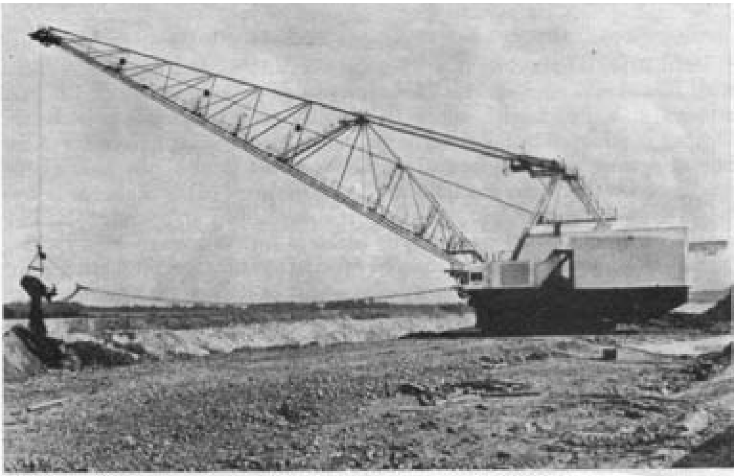


Photo 1.—The Rapier W1400. The largest walking dragline in the world. 20 cu. yd. bucket on a 282 ft. jib.

Photo 2.—Rapier 5366 long-boom face shovel. Bucket capacity 8 cu. yds.

History And Development Of The Bucket Excavator 1 , 2

angle bracings to form channels, but with the necessity for obtaining a longer reach and larger bucket size, light welded lattice booms constructed of mild steel have been developed. One of the largest booms in use today is the 282-ft. tubular steel boom fitted to the Ransome W 1400 Dragline.

Other Front-end Equipments

Two equipments which are in common use on contractors' sites are the drag shovel and skimmer. These two equipments which generally utilize a common boom are fitted to the small multi-purpose machines. The skimmer, used for excavating and levelling ground up to about 18 in.–2 ft. above track level, consists of a bucket suspended from four rollers which run on either side of a main boom. Digging is achieved by pulling the bucket towards the boom head into the face being excavated. The drag shovel is used for trench excavation and consists of a bucket and dipper-arm fitted to the end of the main boom. Its method of digging is achieved by pulling the bucket and dipper downwards in a vertical arc towards the base machine. The largest type of drag shovel so far constructed is one of 2½ cu. yds. bucket capacity. There are two main types of bucket in existence. One which has an opening door to permit ejection of the material and one which has no door and ejects by being lifted until the material falls out under its own weight.

A four-purpose equipment has been developed by one manufacturer which utilizes a common boom for the face shovel, back acter, skimmer and crane. The shovel is of the Luffing boom type described earlier. This multi purpose equipment although economical and versatile does not permit full working efficiency for each rig applied to its own particular role.

Another useful equipment is the clam-shell or grab. It consists of a double-jawed bucket which can be opened or shut by the action of a rope or chain, although some models are operated either electrically or hydraulically. The clam and grab are identical with the exception that the grab is fitted with teeth for the handling of rocks and hard material, whereas the clam has smooth jaws and is designed for handling small granular materials. This equipment utilizes the dragline boom and the same ropes with a slightly different reeving. The first grabs were used in 1870, and the main firm to develop this particular equipment in England was Priestman Bros., one of their machines being used in 1875 in an attempt to salvage treasure from a sunken Spanish galleon.

Giant Excavators

The most interesting and fascinating excavators to be seen today are the giant long-boom machines used on open-cast mine sites, and quarries. Their early development has already been traced, and it is worthy of note that although the U.S.A. now leads in this field, Britain was the pioneer. These are the large walking draglines of up to 45 cu. yds. bucket capacity with booms up to 282 ft., and the large stripping shovels. The latter are used more extensively in the United States than in Britain. Most of these machines employ a unique walking device, but before describing it some mention should be made of the tracked type. The most fascinating and ingenious is that fitted to the Bucyrus Erie 1050 B and the Marion 5561, two excavators of 36 and 40 cu. yds. capacity respectively. Both machines are rigged as shovels and are in use on open-cast coal mines in Pennsylvania. These

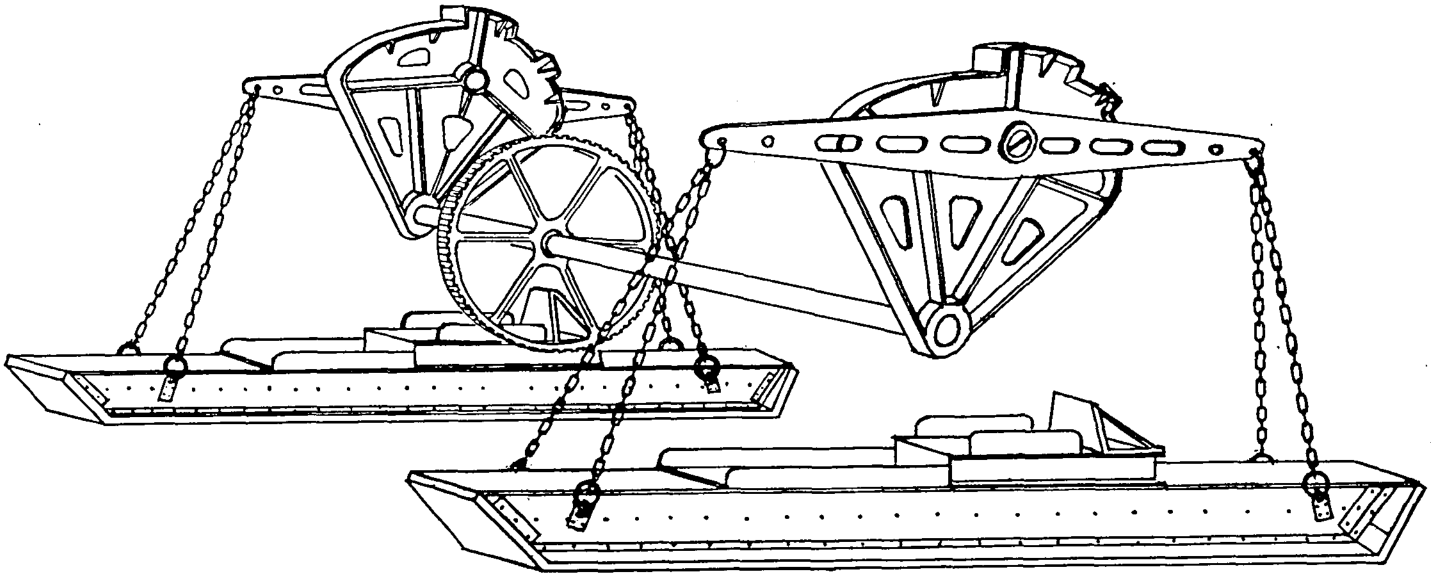


Fig. 3.—The original walking device, 1913.

machines have four pairs of crawlers mounted at each corner of the bottom frame, those on the Bucyrus Erie being driven by separate electric motors, and those on the Marion drive direct from the main machinery. The tracks are joined to the bottom frame by hydraulic rams. An automatic mercury switch which controls electro-hydraulic pumps compensates for unevenness of the ground and thus always ensures that the base machine is level when travelling or working.

A similar travelling and levelling system is used on the "Rapier 5366", the largest stripping shovel manufactured in the United Kingdom. On this machine the tracks are replaced by four sets of four-wheel bogies running on pairs of rails. The total weight of the excavator is 650 tons and it can be rigged with either an 11 cu. yd. bucket and 92 ft. 6 in. boom or an 8 cu. yd. bucket and 104 ft. boom. The dumping radius is 107 ft. and 122 ft. 6 in. respectively.

The walking device which is almost universal on present day large capacity machines originated in 1913. The original device was introduced by the Monighan Co. (U.S.A.) and was called the "Martinson Tractor" after its designer. It consisted of a long shaft running horizontally and at right-angles through the main machinery, with an eccentric segment attached to each end. A carrying bar, from which a timber and steel float was suspended by chains, was rigidly fixed to each segment. The machine had a large circular base on which it rested when working. The method of travel was as follows. As the horizontal shaft was rotated the cams carrying the beams lifted the floats through 180 deg. to press on the ground surface. Further rotation of the shaft brought the cams into contact with plates on top of the floats, gradually raising the rear end of the machine. Further rotation brought the cams up against stops on the floats and thrust the base machine forward. This operation was continuous for the distance the machine was required to move. The disadvantage of this system was that the floats, not being rigidly attached to the carrying bar, often swung under the base of the machine causing the machine to step on its own toes. More than 200 machines incorporating this travelling device were made between 1913 and 1926, when an improved device was introduced. The improved method has remained basically the same since, and briefly it is as follows. The machine has a large circular base which is heavily plated and takes the whole weight of the machine when it is in its working position. Two large floats are suspended from two eccentric cams, one on each end of a long horizontal shaft called the travelling shaft. This shaft is mounted on the underside of the revolving part of the superstructure and is rotated by a direct drive from the main engine. In its working position the excavator sits on its circular base, and in this position the floats swing clear of the ground. When it is desired to travel the machine the travelling shaft is set in motion, thus rotating the two cams. As the cams rotate the shoes press into the ground, lift the machine and force it forward horizontally for a distance of about 6–8 ft. Further rotation raises the shoes and the base is lowered to the ground. Continual rotation of the travelling shaft causes the machine to step backwards at the rate of two to three steps per minute. The action can be best likened to a man walking by means of two crutches, the crutches representing the walking-shoes of the excavator and the man's feet the base.

Obviously it is impossible to lift the loaded circular base vertically due to

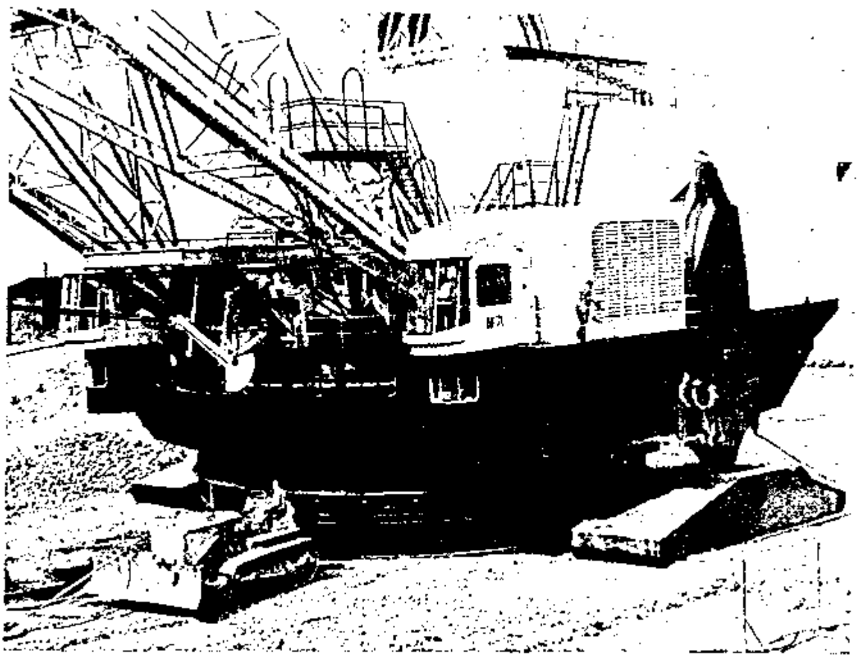


Photo 3.—Rapier W1400 walking dragline. Compare its size with the Size 1 tractor in the foreground. Weight of machine 1650 tons.

the enormous suction between it and the ground. It is therefore necessary to break this suction before the machine can be lifted. This is done by an initial dragging combined with the lifting movement once the shoes start to take the weight of the machine.

Since the total bearing areas of the shoes is less than half that of the base, the full weight of the machine cannot be transferred to the shoes during the lifting action. To achieve this the travelling shaft is offset several feet behind the centre pivot of the superstructure, bringing the centre of gravity well forward of the lifting centre and towards the rear end of the machine. Thus when the apportioned weight of the machine is taken on the shoes during the walking action the front end of the machine, carrying the boom bucket etc., tilts and trails on the ground whilst the rear end is raised some 9–12 in. off the ground.

The largest machine to utilize this device is the British-made Ransomes & Rapier W 1400. This is an all electric machine supplied with power from the National grid. It weighs 1,650 tons and has a 282 ft. boom and a 20 cu. yds. bucket, permitting the machine to excavate some 30 tons of soil per minute and depositing it one-tenth of a mile away. The R.R. W 1400 can be seen towering above the countryside at Corby in Northamptonshire, working on the open-cast iron ore site of Messrs. Stewarts & Lloyds. They were one of the earliest firms to use excavators for open-cast mining, and have done much to encourage the production of large type excavators in this country.

Note.—The author is indebted to Mr. T. W. Broughton, Publicity Manager of Messrs. Ruston Bucyrus Ltd., for his help in compiling this article.

Water Divining as an Aid to Engineering

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

In June, 1956, I was invited to talk to the British Society of Dowsers about my experience in finding water by dowsing in the new H.Q's. project in Mönchen Gladbach.

A general account of the whole project appeared in the *R.E. Journal* of March and June, 1956, in which I made no mention of water divining.

In the *Journal* of December, 1956, Major D. White M.B.E., who was my E. & M. Officer, wrote an account of the electrical and mechanical aspects of the project. In his chapter on water supply he briefly and kindly refers to "a dowser of no little experience and success". I was that dowser—but in writing for the *Journal* we had agreed that the part played by dowsing in proving the source of water for the project should be minimized at that stage because in the engineering world—(and after all, the *R.E. Journal* has its circulation in the engineering world), dowsing is looked upon as not quite respectable.

My talk to the British Society of Dowsers was given in a company whose more advanced theories and practice I cannot understand. I have always felt that their higher aims had tended to obscure and even to discredit the art of simple water divining—I therefore kept my lecture on an earthy plane and related it severely to engineering. I have to thank Colonel Bell, their Chairman, for permission to reproduce the account of the talk as it appeared in their Journal, and for the use of the blocks for the Appendices.

In presenting it to this *Journal* I have amended my title to suit my readers. While retaining the wording of the lecture, I have interpolated in the text further notes of explanation or interest. The whole is intended to show that water divining is an important, sure and practical short cut to the development of water supplies, and a great money saver.

Introducing the lecturer, the Chairman said: In October, 1954, I read in a Sunday newspaper that Colonel Grattan, the officer of the Royal Engineers in charge of the building of the new Army Headquarters near Mönchen Gladbach in Germany, had discovered an ample supply of underground water near the site, entirely by dowsing methods, and that this supply would be much more economical than that from a more distant site favoured by geologists.

I was naturally much interested to learn of this striking example of the value of the dowser's art, and determined to try to get Colonel Grattan to talk to us on his experiences as a water diviner if the opportunity arose.

Colonel Grattan has now retired, and has kindly consented to address us—and here he is.

I am delighted to be given this opportunity to speak, not only to have the honour of addressing your Society but also because the subject, having been reported by the Press in the most sensational and least informative manner, this occasion gives me the chance to reduce it to an account of sober fact.

Colonel Bell has already asked me why I did not so much as mention dowsing in my recent account of the New Headquarters Project in *The Royal Engineers Journal*. I am glad he made this observation as there may be other Sappers in this audience who have had the same thought. I must state that my silence on the subject was not a casual omission.

In 1952 I was appointed Chief Engineer of the £14 million project for the building of a new joint Headquarters, west of the Rhine, for the British and Allied Forces. Water supply, important though it is, was only one of the aspects of this large project. For one reason and another I decided when writing up the project to soft-pedal the share that dowsing had played in the development of the water supply. I intended to devote a later article to an account of this aspect alone, and in fact this occasion is the first published account of my water divining endeavours.

All engineers distrust water divining. I, as Chief Engineer, was not prepared to place uncorroborated reliance on it, nor to put up a case for developing our own water resources on water divining alone. I was fed up with the way the Press had handled early reports of it, and further I felt that my Deputy Director of Works and others were tired of it. But when it became evident that in my private capacity as a dowser I was able to help myself in developing and using our own water I was ready to take full advantage of my gift.

It seldom falls to a dowser to become his own patron with the money and power to employ himself as a dowser. As Chief Engineer I employed my dowser to the full, but also as Chief Engineer I had to keep the subject in proportion.

In 1952 it was decided to build a new headquarters for Northern Army Group and 2nd Tactical Air Force between Mönchen Gladbach and the Dutch border. A site of a thousand acres was chosen, and I, as a member of the Siting Board, naturally asked the local German authorities as we went along whether there were public supplies of water which they could tap for the purposes of the new town. It was confirmed that there were waterworks of moderate size at Uvekoven, Waldniel and Rheindahlen. Please note these places on the map. As you see, the site was well surrounded by waterworks. (Appendix A at the end of this article.)

(*Note.* It may tax the readers' powers of concentration to follow the plan without the aid of a lecturer's pointer, but without some attention to the plan much of this narrative may be difficult to understand. The grid is in kilometre squares. The H.Q. site of 1,000 acres is in the centre of the map and the public Water Works marked $\boxed{W}$ surround the H.Q. site evenly at a few kilometres distance.)

The new headquarters town has now been built and occupied. It has a population of over 9,000 souls. We did not use any of these public water supplies because we found better and cheaper water on our own site. This is the story of its development.

The water supply demand was based on 75 gallons per head per day, or a total of 700,000 gallons a day. Discussion with the German authorities revealed that the several local works would be able, with some increase of their plant and capacity, to provide this amount. The cost of these increases would have to be borne by the project funds. In any case the public water was not of desirable quality. It was slightly alkaline (pH value, over 7) very hard

(21 to 36 degrees) and aggressive, and would tend to give the same trouble in heating and distribution systems as had been experienced in the existing Headquarters at Bad Oeynhausen and Bad Eilsen. However, in the middle of the forest land we had acquired, lived the owner of the land in his hunting lodge. I learned from him that he derived water from his own well at a depth of 23 ft. This water was soft, slightly acid and *entirely different from that supplied by the surrounding waterworks.* My thoughts were, therefore, easily switched to the advantages of developing our own supply. This, if successful, would not only give a more benign water but would also achieve independence, wholly or partially, from German supplies in times of trouble. In principle, the idea of our own waterworks was welcomed by Headquarters Northern Army Group, and I went ahead with plans.

I must confess that I did not at once invoke the aid of water divining. I was too busy with other planning. I first consulted a couple of National Service officers of the Royal Engineers who were geological students, and on their advice we put down trial boreholes of 6 in. diameter in the middle of the site at points G1 and G2. There was a little water at the 23-ft. level, and beyond that nothing more down to 120 ft., where we stopped.

(*Note.* G1 to G18 were gauge bore holes sunk over a period of some months of exploration and numbered in their order of sinking. They were 150 mm. bores, or 6 in. in diameter.)

I was very busy with other planning, but on the following Sunday afternoon I found time to prospect for the first time with a rod. I could find no water to the east of G2, but everywhere to the west of our borings there was a steady pull on the rod, so in consultation with my E. & M. officer we decided to put down trial bores at G3 and G4. The results were spectacular and important. Firstly, water was struck at 23 ft., which confirmed the stratum at the hunting lodge. Secondly, an impervious band of black clay was met from about 45 to 73 ft. below ground, and a course water-bearing gravel from 73 to 96 ft., and below that black and brown clay solid to the bottom of our boring which had to stop at 130 ft. (See Appendix B.)

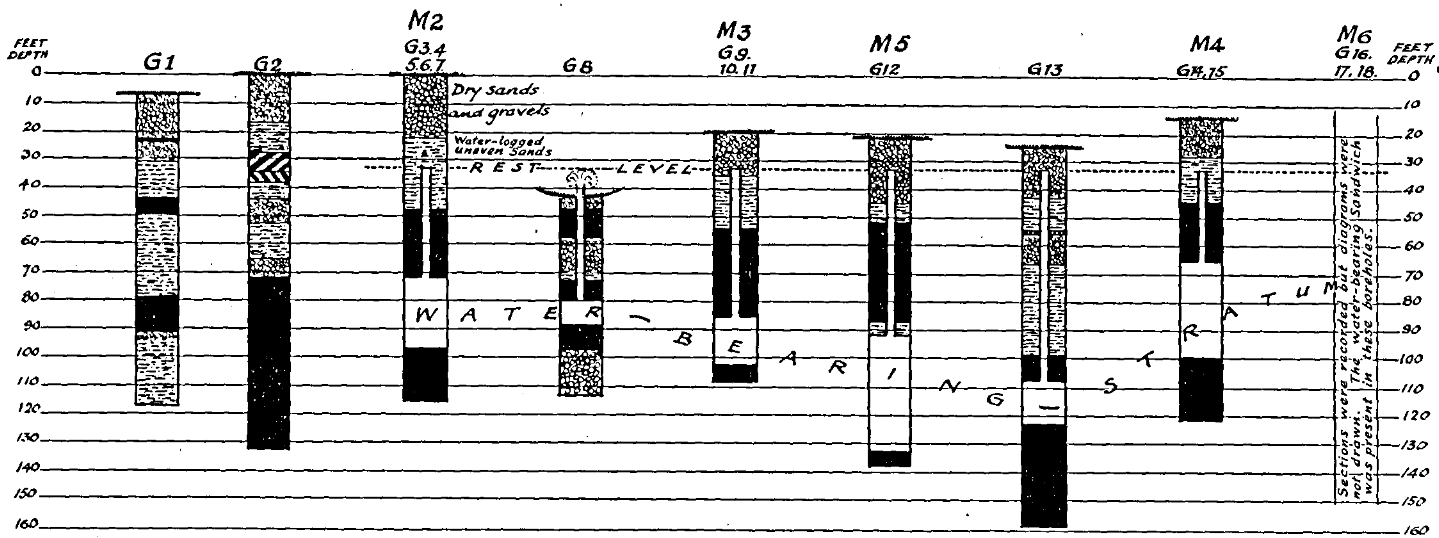
(*Note.* Appendix B does not show the individual stratification of each of the eighteen gauge bores, nor of the six 800 mm. (32 in.) wells which were sunk —this would have been unnecessarily laborious. Each diagram shows the approximate sections of all the bore holes in the group it represents.)

There was discovered therefore, a sandwich of water-bearing gravel between thick strata of clay. I shall repeatedly refer to "the sandwich". The water was fairly soft (15 degrees) and slightly acid (pH 6·7), free from impurities, and well protected from pollution. But what was most exciting was that when the sandwich was penetrated the water rose by artesian effect from this stratum at 76 ft. to 33 ft. below ground level. This dramatic turn I had not expected. I interpreted it as indicating that the sandwich was a closed one under static pressure from a source level with the artesian rest level. This, I thought, must be far away in the hills along the Dutch border.

The next step was to sink a well which could be pumped in order to ascertain quantities. So we put down a control group of bores, an 80 cm. (32 in.) bore at M2, surrounded at 50 yards' distance by three gauge bores G5, 6 and 7. We would then pump the well at a rate commensurate with our final requirement and observe yields, pumping levels and recovery rates in M2 and its surrounding gauge bores. The siting of this group was based as

BOREHOLE STRATA

Appendix B



Each diagram shows the average section of a group of boreholes.

There was little variation between bores within the group. G1 and G2 showed confused strata. The remainder all showed the sandwich of water-bearing gravel between dense clay strata.

Note the artesian rest level.

M holes were 80 cm. wells. G holes were 15 cm. gauge bores.

much on planning convenience as on any other factor, as there was a uniformly strong stress on the divining rod anywhere on the site to the west. No point seemed in that sense more favoured than another.

We pumped M2 at the rate of 15,000 gallons an hour for seven days ($2\frac{1}{2}$ million gallons). During pumping the level in M2 fell 30 ft. to -66, which was still 10 ft. above stratum level.

The gauge bores G5, 6 and 7 were not unduly influenced. What was even more vital was that the rest level rose with great speed when pumping ceased, being restored nearly to normal in 15 minutes. The first indications seemed highly favourable. I considered that if the yield was sustained over three weeks' pumping, at a reasonable rate, and that the purity was maintained, and the recovery rate after cessation of pumping was still satisfactory, it only remained to discover the extent of the water-bearing field to establish whether it was worth going ahead with the development of our own waterworks. On the face of it, it appeared that three such wells, as we had already bored, could be calculated to provide sufficient water for the permanent population of the Headquarters town, *provided the source was sufficiently extensive.* The picture of our own waterworks with its surrounding wells, providing top quality water at a comparatively small cost was forming in my mind. It only remained to prove the extent of the source and to obtain approval to developing it in preference to employing the public supplies. In confirmation I proceeded with several more bore holes at G8, M3, G9, G10, G11 and G12, and each one showed much the same characteristic stratification and yielded water of the same analytical quality. The bore at G8 was for fun, bored in the valley for no other purpose than to give visual demonstration of the artesian effect—for the ground level there was below artesian rest level. The bore welled up with water when the sandwich was broached and it had to be plugged off. The exercise gave us much pleasure!

At this juncture I called in the German geologists to give their advice. There were public waterworks in the vicinity and some miles to the south of our site there were extensive brown coal (lignite) workings, so I felt certain of reliable geological opinion, but I wanted geological corroboration. The German authorities were already making it plain to me that they were not in favour of pursuing our exploration. After all, there were reliable waterworks within reach which could supply Headquarters needs, if we subscribed to the modernization of their plant. They obviously thought it a waste of effort and money to go on with the costly adventures of the *Wünschelrutengänger* (wishing-rod walker). The German building authorities through whom all my work was done, therefore announced their intention to discontinue boring unless the German geologists endorsed my wishes. I thereupon took the precaution of phoning my chief engineer, General Sugden, to get him and the Major-General i/c Administration to write me a letter *ordering me to continue water explorations* with the object of achieving, for security reasons, at least a measure of independence from local public supplies of water.

This authority arrived just in time.

At our next meeting the geologists explained that a geological fault ran across the middle of our site. This fault, they explained, was a break in the top of a saddle. We should find no water anywhere near it. In this they had already been proved right, for it was exactly where we had bored the first trials G1 and G2, and we could not have chosen a more unlikely place to find water. The fault is shown on the map at Appendix A. They were interested and impressed with the records of water found and pumped at M2, but gave the opinion that this was a limited source which would be bounded on the east by the geological fault and on the west by the Schwalm River. (Appendix A.) They thought the source would soon peter out. However, the orders I had just received from my High Command to continue exploration were undeniable, and the building authorities agreed to continue explorations under my orders in spite of the unhopeful findings of the geologists. Shrugging their shoulders, the party politely departed. I continued water divining and found, as the Germans had declared, that there was a strong demarkation along the fault line. To the east of it there was no indication of water and to the west a strong and even pull everywhere; the line of the fault was thus most definitely and sharply marked. One pace from east to west would take one over a zone of no indication to that of a strong pull. It is interesting to note the strata record of borings G1 and G2 (Appendix B). They were confused and without pattern. In one of these holes pieces of hardened timber at the beginning of its transformation to the fossilized state were brought up by the scoop from 80 ft. This gave further confirmation of the earth fault that the geologists had described.

To establish the extent of the water field it remained to explore farther westward. I did not believe that the trivial surface feature of the Schwalm stream lying at the level of −50 ft. could have much bearing on the underground strata at 60 to 120 ft. depth. Moreover, the sandwich, as proved on our estate, had artesian quality, so I surmised that it was nourished from the hills away to the west. Without delay, therefore, I took to horse (literally) and rode off to the west. Firstly I discovered that the behaviour of the rod is in no degree lessened by being mounted on horseback, and secondly, I observed that the strong and even pull of it as I left my boundary and crossed the Schwalm, continued undiminished. The indication of underground water appeared to continue unabated as far to the west as I could ride that Sunday evening. I surmised, therefore, that the sandwich continued westwards and was *not* bounded by the Schwalm. To confirm this by boring was my next move. I obtained through the British Resident a temporary requisition of a patch in the crops at G13, 1½ km. west of the site, and ordered a borehole there. *The stratum pattern at G13 was markedly similar to that in the several boreholes on the site.* The chemical and biological analysis also showed with certainty that it was the same water. It looked at this stage very much as if the water-bearing field might prove sufficient to sustain our population. However, I said little to anybody until I had been able to prove more.

I then prospected farther afield by car and soon ascertained that north of Arsbeck to the west there was no pull on the rod, but that at a point X on the track near Merbeck village the same steady pull was resumed. By riding or walking outwards on the country tracks from the centre I could eventually reach the boundary of what I believed to be our water source. As I proceeded on each radial track I reached points where, with absolute suddenness, the indication stopped. In this way I was able, bit by bit, to draw the line which enclosed our water-bearing source. This process was full of excitement. For instance, I first established how the boundary ran by Merbeck and then southward in a curve towards Klinkum and then apparently firmly southwards so that it appeared at one time as if the German waterworks at

Uvekoven would fall within my boundary. This would have spoilt everything, I thought, *because I knew their water was entirely different.* But as I traced the line nearer and nearer towards Uvekoven it suddenly jinked eastwards and missed the waterworks by a bare 300 yds. It was unbelievable. Tracing similarly to the north again, the same occurred, for my unfolding line took me through Lüttelforst up towards Waldniel where the other waterworks was situated. Again as I approached the great water tower the line jinked off and missed it by ½ km. and turned hard right towards our site. To the east I already knew that the Mönchen Gladbach waterworks were out beyond the geological fault which bounded our sandwich. And as to the south-east at Rheindahlen the same could be assumed.

There was one point in my delineation which puzzled me for a long time. I knew that the Waldniel supply was of different water to ours by its analysis, but, try as I would, I could find no break in my dowsing along the main road between our western boundary and Waldniel. The pull on the rod was continuously firm and even the whole way. This led me to wonder whether my source and that of the Waldniel waterworks were superimposed or mixed up where they met. But with perseverance I solved the problem. Having found that the rod behaved with equal force whether I was walking or mounted or riding in a car, I had prospected this straight length of road several times by car, and failed to find the edge of my field of water. Even when I walked it all I missed the edge at first until at the second attempt I sensed a weakness or change at point Y. With care I then discovered that for *ONE pace only*, there was no pull and no indication. One more pace northward took me into the Waldniel field. The two fields were separate, but only just. When this point had been cleared up my boundary was completely identified to my personal satisfaction. It is shown in broken line on the plan. Everywhere within this line I was convinced lay my sandwich. It is interesting to note how it joined up with the known geological fault. It is incomplete in the S.E. corner because I did no more than a rough search on horseback and did not mark it on the map and close the delineation.

This all sounds fairly self-confident, but I had still made no official report about my intentions because I refused to advertise the infallibility of water divining without the physical confirmation of boring. I felt it should be easy to confirm, and so it proved, for I then put down three more bores on the western flanks of my sandwich at G16, G17 and G18. It will be observed from the plan that G18 was within 400 yds. of the Uvekoven waterworks. The characteristic stratum patterns of these three far distant wells were very much like the pattern shown in other borings we had sunk within the sandwich area. I was delighted, for I had found the extent of the water source by dowsing and we had proved it by engineering.

It may be asked that in a province of large cities and many small towns how did the Germans not discover the greatly superior water which I was now in the process of finding. The reason lay in the fact that good water in small quantity, sufficient for village and farm needs, was found at 23 ft. everywhere over this site. Having been found there, the need to bore lower, as we had done, had not existed. The amazing thing was that those who had originally prospected for waterworks at Uvekoven and Waldniel had been so unfortunate as to miss our sandwich by so little.

At this stage I felt entitled to recommend officially to my Headquarters that we should develop our own waterworks and be entirely independent of the Germans. The area enclosed by the dotted line is 11 sq. miles. The average thickness of the water-bearing stratum shown by borings is about 17 feet. Assuming then that this water-bearing stratum consisted of 75 per cent gravel and sand and 25 per cent water, it was simple to calculate that even if there were no annual replenishment by nature, the bulk of water standing there would be sufficient at our rate of requirement to last for forty years. As there must in fact be a seasonal topping up of the source I think it is proved that the waterworks which is now running and supplying the Headquarters town is a permanent and profitable undertaking.

It is certain that I would not have succeeded without the aid of dowsing, supported by the findings of actual boring, in persuading myself, let alone my Headquarters, that it would be sound to spend money on our own waterworks. In the event the financial advantages were considerable and lasting. The cost of the four wells, which were eventually developed at M2, M4, M5 and M6, with their pumps and mains, and the waterworks building and plant, was about £50,000. It is doubtful whether we should have spent less if called upon to increase the capacity of the German waterworks and to lay mains from them to our site. The concessional rate for water which we should have been charged by German public undertakings would have been 20 pfennigs per cubic metre, which works out at £20,000 per annum for our needs. I believe the cost of pumping our own is proving very much less than this. Further, we have a water which is in every way admirable for heating and for pipes, for shaving and for drinking. This cannot be said of the public water. I am fortunate to have had the gift of water divining and, at the same time, the power to use it to so much advantage.

(*Note.* Bore hole M3 was abandoned partly because loose clay somewhere at its foot caused it to run cloudy. In fact, a change of plan necessitated using the site of this bore for buildings, so it would have been abandoned in any case.

M5 was put down near G12 (an established gauge bore), and M6 in an area unexplored by preliminary boring, where the indication of water was strong and the position was distant from buildings. The final bore holes which were equipped with pumping gear were therefore M2, M4, M5 and M6. To quote from Major White's account in the *Journal* of December 1956—"the maximum daily requirements can thus be obtained by pumping two bore holes for 17 hours, or three for 11 hours. By operating a systematic pumping cycle adequate rest periods of each bore hole are ensured.")

Before concluding, I would like to revert to my early statement that engineers distrust water divining. I am aware of the eminence of my audience in this field. Many of you have developed the art of dowsing in a high degree and have attempted to enlarge its scope and give it scientific grounding. I know nothing of its theory and am content to enjoy the gift without question. (I have had one or two other small but useful successes in India.) Though I am your guest tonight, I am getting ready to trail my coat-tails and be embroiled in argument. My plea is that dowsing should be confined to its ancient, useful and once-honourable function of divining water. A generation ago water diviners restricted their activities to finding water. Their success was measured by the regard in which they were held and in some cases the high remuneration they enjoyed. In recent years dowsing has been credited by writers and other enthusiasts with powers which I personally believe it does not possess. This has robbed it of the confidence and respectability it once enjoyed. I have heard it claimed that minerals can be found by dowsing. This may be true, but are there not more reliable ways of finding minerals? I have heard it said that water can be found by dowsing over a map—or that a criminal may be tracked down by it, or even that the sex of the unborn child can be determined by swinging a pendulum over the hopeful mother! Where does all this lead one? I know I am in the presence of a society whose investigations are directed towards the medical aspects of dowsing, but I sincerely believe and dare to opine that these somewhat occult activities have achieved little beyond academic interest and have failed more often than they have succeeded. I submit that this in itself would not matter except that the new language and science have grievously detracted from the reputation of the old art as a proven means, when combined with engineering, of exploring for water.

All I have sought to do tonight is to describe the course and results of a large and successful dowsing enterprise. I prefer to believe that there are more things in heaven and earth than are dreamt of in our philosophy, and to class this very personal gift of dowsing as one of them.

* * * * *

The concluding opinions in this talk led to a good deal of discussion and that led me to further reading on the subject. The experts do not all acknowledge that dowsing is an art for which an individual is endowed with the gift. They tend to think that it can be developed by anybody who perseveres. I do not know whether this is the case. Of my two sons one is sensitive to the forces which exist, the other is not. The one who is not sensitive regards the whole thing as "phoney". This is the attitude which most people are tempted to adopt who have themselves not experienced the forces which the water diviner feels. I think about half the population is in some degree sensitive to the phenomenon, and I believe that those who are can increase their sensitivity by repeated practice. Moreover, I think practice enables the user to interpret with increasing sureness what he feels, particularly if the opportunity arises to put his feelings to the test. Dowsing can be useful and important to Sappers if they will apply themselves to developing the faculty.

To be a success one has to be fortunate enough to be presented with an actual problem and to be able to put ones findings into practice. Without opportunities the game remains in the realms of theory or experiment. I have had the opportunity on two other occasions to put water divining to the test. Compared with the one I have described they were of minute importance—but they were none the less interesting and genuine tests.

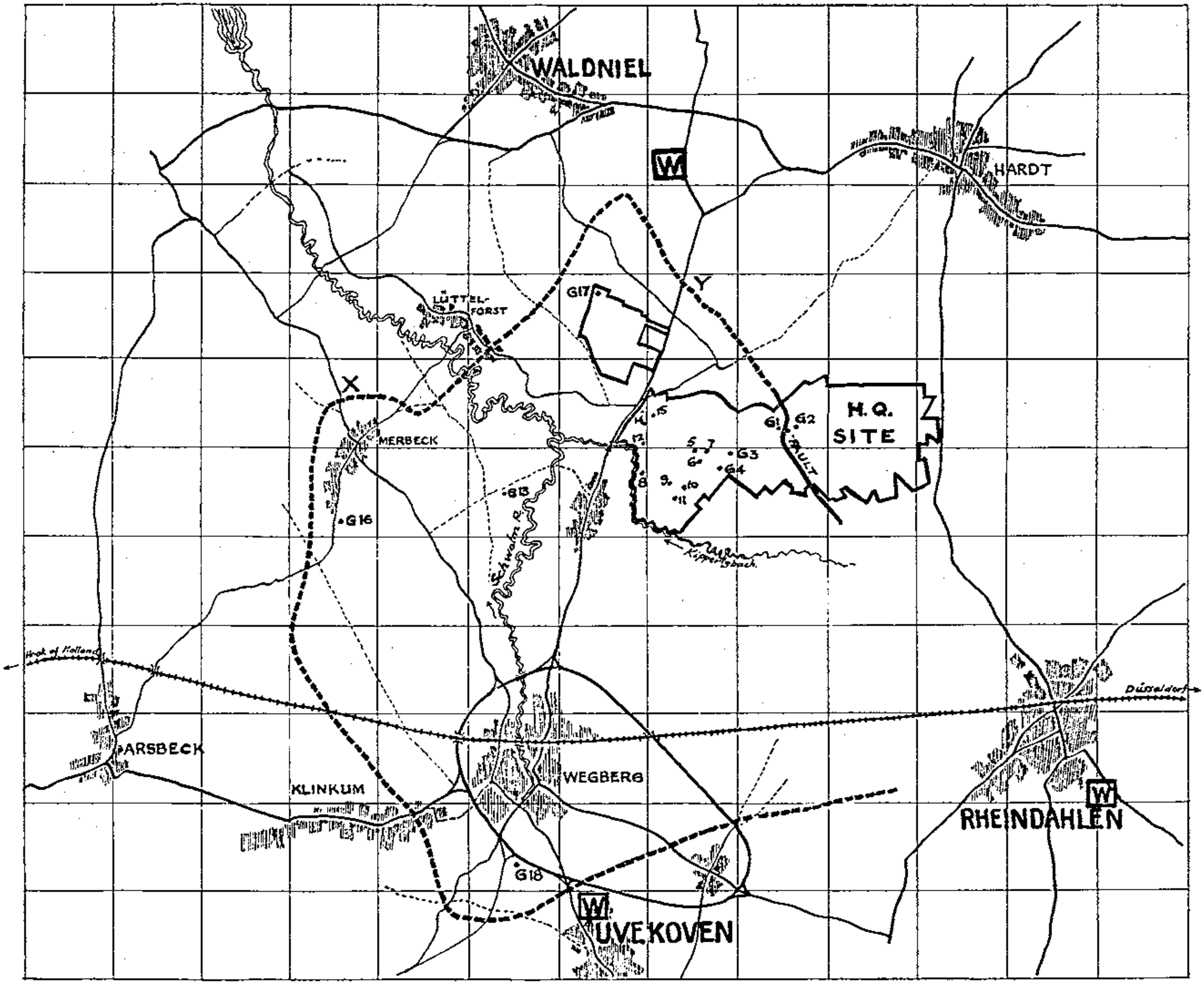
In 1935, as G.E. in Parachinar in the Kurram Valley, I was asked by the Commandant of the Kurram Militia to find a site for an alternative well at one of his outposts. The Militia post of Kharlachi stood on a knoll within 200 yards of the Afghan border, in the upland of the valley. The well from which the post drew its water lay in the valley on the Afghan side. When times were hostile the water mules were sniped by the Afghans from the over-looking hills and water had to be drawn under some risk at night. If there was bright moonlight water had to be brought from Parachinar, about 11 miles by mule. This was a nuisance! A well on the lee side of the knoll from the Afghans would be protected in dead ground. I was asked to see what I could do. The site was arid, stony and unpromising—and the Turi well diggers doubted the presence of water on the side away from the river. However, I tried with my rod and to my satisfaction sensed a minor but positive reaction in the dead ground behind the knoll. By the 45 deg. rule I surmised that the depth would be about 30 ft. below ground. Well diggers were employed and water was found at 32 ft. Thereafter the post was watered safely at any time and they all lived happily ever after!

In another part of tribal territory, which was administered by the Deputy Commissioner Kohat and was known as the Shia Salient, I was asked by the D.C. to find water to solve a problem. There was a steep, narrow nullah forming the boundary between two mutually ill-disposed tribes, and the only well in the vicinity lay a few yards across the dry bottom of this nullah on its west bank. In times of strife the tenuous agreement whereby the two tribes normally shared the well would break down—and each side would snipe the women of the other when they crept down at night to draw water. Up to that time no other dry-weather source had been found. Anybody who knows the Pathan's everyday rivalries in *zumke, oboe, khazha* (land, water and women) will appreciate the intensity of enmity that the sharing of this perilous well induced. So the D.C. and I rode out half a day in the burning sun with our *baddragga* to a parched and stony hillside. Hardly thinking I should be successful I covered the ground with my divining rod. I was able to locate water in the territory of the tribe on the east of the nullah. With much incredulous solemnity the elders put their well-diggers on to the task and I had the satisfaction of hearing later that the new well had been successful and had relieved the local tension.

Now these two incidents, trivial though they were, occurred in localities where water is very scarce and therefore important. In such places the trade of well digging is passed down in families who are said to have a special nose for water, and are frequently successful in finding it. I never met any who practised dowsing as we do in Europe, but it may well be that they can feel the same influence which causes a twig to turn in the hand of the European dowser. All I can say is that in neither of the cases described did the local well diggers offer any hope of water, whereas dowsing was profitably employed in finding the small underground streams which were sufficient to meet the needs.

For Sappers the moral of this is that as long as our motto is "Ubique", we shall find ourselves in parts of the world where the dowser, if he takes it seriously and can have command of the tools to finish the job, will find the power of water divining a useful and reliable addition to his equipment.

May others have the opportunity and good fortune which has fallen to me in this interesting field.



Scale: Squares are 1 Kilometre

[W] Public Waterworks at Waldniel, Uvekoven and Rheindahlen

▪▪▪ Boundary of water-bearing area as found by dowsing

G 1–18 Boreholes to prove strata; G 13, 16, 17, 18 outside H.Q. site

The positions of the M wells are: M1 midway between G 1 and 2; M2 between 5, 6, and 7; M3 between 9, 10, and 11; M4 by 14 and 15; M5 near 12; M6 c. 300m. E. of 15.

The Erection of Buildings in East Africa to accommodate a Combined Army and R.A.F. Wireless Project

By MAJOR E. A. SHAND, R.E.

This paper was read by the author to the East African Association of Engineers

GENERAL SCOPE OF THE WORK

The Wireless Stations themselves each consist of three parts, the Receiver Station, the Transmitter Station and the Control Station. These are entirely separate buildings on separate sites which are several miles apart. The full scope of the work in East Africa covered the construction of each one of these stations for the Army and for the R.A.F. The R.A.F. Works Organization undertook the construction of the two Control Stations, while the Royal Engineers' task was the building of the two Receivers and the two Transmitter Stations. It is this latter work, for which we were responsible, that I now wish to describe.

The total value of the constructional work for which the R.E. were responsible was over £360,000, this value does not include cost of stores and machinery, etc., supplied by the W.D. The method of execution was the normal one of contracts let to competitive tender.

SPECIFICATION AND DESIGN GENERALLY

All the buildings are in high class permanent construction, stone walls, terrazzo or wood block floors, steel roof trusses and cedar shingle roofs, and were designed by a London firm of architects engaged by the War Office. The same firm also was employed by the Air Ministry.

All walls were designed in irregular coursed quarry dressed rubble stone work. A striking effect has been obtained by selecting stone of varying colours from four separate quarries, and a recessed joint was made by knocking off the face edges of the stone about ½ in. back, and ruling the joint with a ⅜ in. diameter reinforcing bar, all salient angles were finely chiselled. Difficulty was experienced in getting local masons to work to the sample colour panels erected, but after a while they co-operated well. Above D.P.C. a gauged lime mortar was used, a good hydrated lime was obtained locally. Local limes varied in colour considerably, and for stonework a lime of a light colour was insisted upon, while the very dark coral lime from Mombasa was used for the rendering coat on internal wall plaster. Gauge rods were set out for all buildings giving the sequence of irregular courses.

The W.D. standard specification was worked to for all concrete work, except suspended reinforced slabs over cable crypts, for all this work, aggregates were tested and graded by the P.W.D. Materials Laboratory, who produced a design mix. Results at first were poor, caused mainly by the site concreting organization, but having insisted that the African ate his sugar cane and mealies, etc., away from the stacks of aggregate, the average of tests were maintained at 3,500 lb. sq. in. after 28 days. Test cubes from all reinforced work were dispatched to P.W.D. for testing and records were maintained for all results.

All external woodwork for joinery was in mvuli, a timber which is grown mainly in Uganda; this only required a coat of linseed oil to produce a dark finish which contrasted well with the stonework. The quality of all joinery work was excellent.

The main roofs were covered by cedar shingles. Some doubt was felt as to their length of life, as the hot sun during the day and the cold nights produce large temperature ranges. To prolong their life the shingles were dipped in a Penta-Chloro-Phenol (P.C.P.) type of wood preservative.

For prevention of "termite" attack all sites were covered with a 1-in. thick coat of a mixture of P.C.P. and stone-dust, which was obtained by a 5 per cent solution made of Penta-Chloro-Phenol in fuel oil, mixed in a mechanical mixer with stone-dust at the rate of 5 gallons to 9 cu. ft. of stone-dust.

Where buildings were sited on black cotton soil all soil was removed to 4 ft. beyond the external walls. This was done to prevent the foundation walls being "squeezed", as black cotton soil moves considerably.

R.A.F. Transmitter Building

The plan of the main building was original, being in the shape of an aeroplane. Photo No. 1 was taken facing north-west, this is the front elevation and represents one of the wings of the plane. The fuselage and tail of the plane were made up of similar type of buildings.

Under the main floor the cable crypts followed the shape of the building, these crypts were 4 ft. 6 in. deep and 4 ft. 9 in. wide, they were "tanked" by a D.P.C. laid in hot bitumen between a skin of concrete and the main walls.

Photo 1.—R.A.F. Transmitter Hall, exterior, West Wing.

Photo 2.—R.A.F. Transmitter Hall, interior, East Wing.

The floor area (21,000 f.s.) was mainly finished in terrazzo and some idea of the size of the Transmitter Hall can be obtained from Photo No. 2 which shows the East Wing. The West, North and South Wings were almost similar, the photo being taken from the central junction.

The roof design was unusual, the main Transmitter Hall roof was made up of steel trusses and timber members covered with cedar shingles, the steel trusses are shown in Photo No. 2. At the end of each wing were aerial exchanges, these are semi-circular on plan and they were roofed in an unorthodox manner, a reinforced concrete corbel was supported on two legs 28 ft. high. From a purpose made steel collar, on the corbel, ran six No. 15 × 6 in. R.S.Js. as radials to the outer wall, shown in Photo No. 3. Purlins and rafters were fixed to the radials then covered with 1-in. boarding. The boarding was then covered with ½ in. termite proof insulating boarding and finally with aluminium sheets.

The Power House was designed to take two 300 kW. stand-by generating sets in the main hall. It has two double storied wings which accommodate the radiators and water tanks. The specification was similar to the main building and had no unusual features.

Some figures might be of interest to indicate the size of the Transmitter Building: 45,000 f.c. of concrete was poured using nothing larger than a 10/7 mixer; 46½ tons of steel were fabricated in Nairobi, transported and fixed on site. The cable crypts required 25,000 f.s. of shuttering, the concreting of the crypt was continuous, the vertical shuttering was stripped after 5 days; 17 tons of reinforcing steel were used in the floor covering the crypts and in the reinforced corbels to the aerial exchanges. All excavation was done by hand and over 100,000 f.c. was removed.

RAF Transmitter Hall,Interior Est Wing

Photo 3.—R.A.F. Transmitter Hall, showing steel collar on top of corbel for fixing R.S.J. roofing radials for carrying purlins and rafters at curved ends of buildings.

Army Transmitter Building

Again the architect produced some unusual features, as is seen from Photo No. 4, the 45-ft. open span trusses in the main Transmitter Hall carried flat roofs on both sides. Those flat roofs were carried on rafters which were notched at one end to a channel welded to the tie-beams of the trusses, and were supported at the other end on the main walls of the building. The rafters were boarded, then covered with "Diatomite" insulating blocks, concrete screed, and finally with two layers of roofing felt laid in hot bitumen.

The projecting truss members were "sheathed" in aluminium and weathered with sheet lead, also the vertical panels between the clerestory windows were finished in aluminium. The main roofs were "shingled".

The cable crypts under this building were deeper than in the R.A.F. Transmitter, being 6 ft. 6 in. deep by 4 ft. 3 in. wide, their construction was similar to the R.A.F. and 20,000 f.s. of shuttering was used.

The main Transmitter Hall (see Photo No. 4) had a floor area of 17,000 f.s.

RAF Transmitter Hall,Interior Est Wing 3

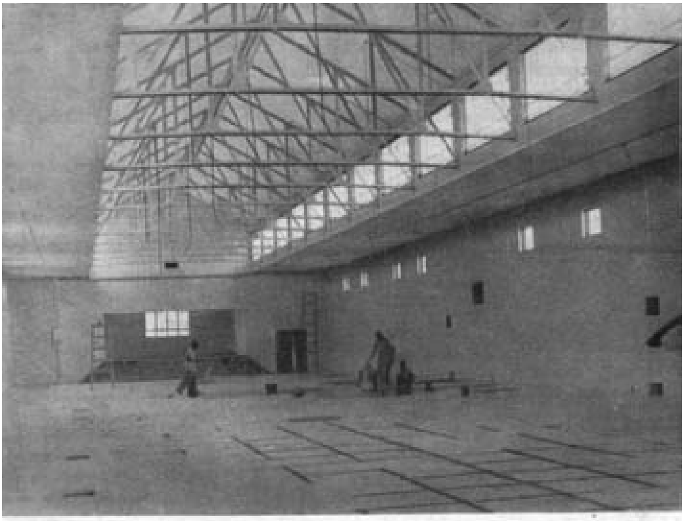


Photo 4.—Army Transmitter Hall, interior.

Photo 5.—Army Transmitter Hall, exterior, showing "blower" houses.

The Erection Of Buildings In East Africa 4,5

in terrazzo. Outside are the "blower" houses which supply ventilation to the Transmitter sets inside the main hall (see Photo No. 5 which also shows the finished roofing).

An "L" shaped wing provided for offices, sanitation, workshops and stores.

As in all other buildings, the decoration scheme was a departure from what is usually imagined as normal W.D. practice. Referring to Photo No. 4 again, the end walls were in french beige, the sides in french grey, ceilings white, woodwork and steel work to ceilings in arctic blue and doors, etc., in terra cotta. All excavation was done by hand and 20,000 f.c. was removed.

Power House

This building was designed to accommodate two 350 kW. "Bellis & Morcom" generating sets.

The bases for these engines were concrete blocks 22×10×8 ft. resting on a 2-in. thick layer of cork matting with a 3-in. air gap round the sides. The engines were a W.D. supply having been removed from Mackinnon Road, these were installed by Messrs. Balfour & Beatty & Co. Ltd. as a separate contract.

Army and R.A.F. Receiver Buildings

The construction of the two Receiver Buildings and their respective power houses was let as a single contract for £30,000. Although this simplified the contract documents it caused difficulties in separating costs between the Army and R.A.F. considerably. The Army Receiver Building was similar in plan to its Transmitter, although very much smaller, being only 4,900 f.s. in area.

This building was sited in hollow ground, and as the whole of the main Receiver Hall with its cable crypt had been excavated out 4 ft. clear of the building it acted as a tank for all sub-soil water which drained towards it. The building was not allowed to be moved owing to its relation to the rhombic aerial sites. Therefore a drainage channel of an average 7 ft. deep had to be dug to drain this building site, and War Office provided further funds to cover this work.

The Power House was designed to accommodate a 70 kW. "National" gas engine with automatic main failure switching arrangements. No photographs exist for this building.

The R.A.F. Receiver Building was very small, being only 2,300 f.s. in floor area. It had no cable crypts, only wiring ducts. The Power House accommodated a 55 kW. "Crossley" diesel generator set, with automatic mains failure start switchgear.

Mast Foundations

As in the architectural design of buildings, the Army and the R.A.F. masts differed considerably. The Army masts were designed as lattice towers 105 ft. high, each tower resting on four concrete blocks, of approximately 80 f.c. each. On the Army Receiver and Transmitter sites there were a total of sixty-three towers, set out as directional rhomboids, covering 800 acres of ground. The R.A.F. had 147 tubular steel masts varying between 118 ft. and 88 ft. high on their two sites covering 700 acres. Those also were set out as directional rhomboids. Each mast was "guyed" and supported by ten concrete blocks of 64 f.c. each. The guy foundation blocks were difficult to set out as some masts were common to two rhomboids. The angle made by the intersecting axis was bisected, the guy bases were then set out at 45 deg. to the bisecting line.

The setting out of rhomboids was done on theodolite traverse carried out by the R.E. surveyor, mentioned later. Pegs were set giving centres of masts or towers, these fixed the lengths of the major and minor axis of each rhomboid which were 900 and 340 ft. respectively. All the mast foundation work was let as a single contract for £34,000, this again required careful control of costs between the Army and the R.A.F.

Guard Accommodation

Married accommodation for twenty-three wardens was provided at the Army Receiver site only. The R.A.F. did not require accommodation as their police guards were supplied by the civil police.

This accommodation was divided into:

Type X Quarters	Detached W/officers Quarters	1 No.
Type Y Quarters	(4 Double Roomed Quarters)	1 Block
Type Z Quarters	(6 Single Roomed Quarters)	3 Blocks

The original contract was for one Type "Y", one Type "Z" and four Guardrooms, one on each site. This was accepted at £10,661. The additional two No. Type "Z" Blocks were let for £6,591 as a further contract at a later date.

This native accommodation was of a high standard, providing water-borne sewage and showers for men and women in an annexe to each block. Each quarter was supplied with electric lighting, cooking facilities, and built-in cupboards. The detached quarter for the African W/Officer was equal to many quarters occupied by Europeans in Nairobi.

All accommodation was sited on the Receiver site owing to the lack of water at the Transmitter site. This has led to complications in ferrying personnel between sites. Now that a survey for water has been successful, additional accommodation for guards might be built on the Transmitter site.

Land Purchase

Receiver Sites

A total of 1,000 acres was purchased, which is now divided into the Army Receiver site (600 acres) and the R.A.F. Receiver site (400 acres).

The Army site accommodated the main Receiver Building, its stand-by Power House, a Guardroom and married accommodation for twenty-three wardens. On this site also were forty-three Aerial Towers 105 ft. in height laid out as directional rhomboids.

The R.A.F. site accommodated the Receiver Hall, its Power House, Guardroom and seventy-two Mast Bases on which were erected masts 88 ft. in height, also set out as directional rhomboids.

The Receiver sites were 3½ miles from the main road and it was necessary to obtain a 55-ft. way-leave through three farms to construct a suitable murram access road. In conjunction with the respective farmers the road was fenced and gated, these works were carried out as a separate contract before work commenced on the building sites.

On completion of the installation of wireless sets, machinery and masts, etc., the road was finally surfaced. The soil on these sites was mostly black cotton soil.

Water for the Receiver sites was provided from a bore-hole sunk within the boundary to a depth of 169 ft. and pumped to a 12,000 gallon storage tank 30 ft. high. This work was completed by contract before building commenced.

Army Transmitter Site

A total of 200 acres was purchased for this site which was 2½ miles from the main road, served to the entrance by a district council murram road. A short approach road was constructed, as the soil on this site was hard murram no difficulties were encountered. This site provided accommodation for the Transmitter Hall, its Power House, twenty Aerial Towers set out as directional rhomboids and a Guardroom.

Water was not supplied to this site, a 3,000 gallon overhead storage tank was erected with a pump to draw from water tankers. A geophysical survey has been carried out by the P.W.D. and it indicates that water in sufficient quantity would be found on site. A scheme has been put up to the War Office to supply water to this site.

R.A.F. Transmitter Site

This site was adjacent to a main tarmac road and occupied 360 acres. A district council road ran through the area required and it was agreed that this road would be diverted around the new boundary and made up to Council's specification at Air Ministry expense. This road was murram surfaced and was constructed upon a portion of the area purchased by the Air Ministry.

The site accommodated the Transmitter Building, its Power House, a Guardroom and seventy-five Mast Bases set out as directional rhomboids.

Water for this site was provided from a bore-hole sunk within the boundary to a depth of 270 ft. and pumped to a 3,000 gallon storage tank. The building contractor had only to supply a temporary pump which would be replaced by an Air Ministry pump on completion of the work. The bore-hole was purchased with the land.

Provision Of Stores

The W.D. were responsible for the supply of cement, constructional steel, reinforced steel, steel windows and certain electrical fittings. Priced schedules giving the rates for all these materials were issued to contractors tendering, before they priced the "Bills of Quantities".

Site Problems

Progress Charts

Before construction commenced on the main buildings, progress charts were produced by the R.E. These charts were made up from the Bills of Quantities, each operation being confined to a definite stage in construction, i.e., excavator, mason, roofing, etc. Each operation was reckoned, as a percentage of the total of the Bills of Quantities. These charts were kept up to date at G.H.Q. by fortnightly returns from the site, and they provided a record of actual progress and sufficient financial data on which to check contractors' bills.

Constructional Steel—(130 Tons)

This was originally ordered in the U.K. by the War Office, through the Iron and Steel Federation, to be made available in May, 1951, but owing to difficulties in dates of delivery and shipping, the Chief Engineer was asked to accept wooden trusses locally made. Taking into consideration the high specification called for, the Chief Engineer decided not to accept wooden trusses and pressed for steel to be made available early. It was agreed that the steel would be made available from R.E. stocks held in Egypt, although the sizes available were not exactly to requirements. This meant revision of steel sizes and substitutions, and when finally all concerned agreed to the substitutions, the steel was ordered. Unfortunately, the day the steel was due to be loaded coincided with the abrogation of the Canal Treaty and to avoid incidents the ship left hurriedly without the steel.

After more delay, the steel was finally loaded on to a ship which, for a reason undiscovered, off-loaded it at Aden.

During all these irritating delays, the C.R.E. staff were again considering the use of wooden trusses, trying to find steel locally in Nairobi and at Mackinnon Road. Finally, however, the steel arrived at Mombasa from Aden, and was delivered in Nairobi in early May, 1952, but in two cases fate, or a clerk at Mombasa, was responsible for several truck loads arriving at Kahawa C.O.D. instead of Nairobi C.O.D., 13 miles farther along the line.

All these delays extended the contract completion dates considerably, from February and April to September and November, 1952, for the Army and R.A.F. Transmitters respectively. Steel was the largest problem of all, but once in Nairobi all went well.

All trusses, R.S.Js., stanchions, etc., were fabricated in Nairobi, the large trusses for 45 and 35 ft. spans were transported in halves, all joints in the half-section were welded. When erected the half-sections were bolted together by a short tie beam length, and at the crown of the truss.

Cement (1,200 Tons)

The first consignment received was in jute bags from Egypt and rumours concerning this cement began to spread. It was said, it had travelled between Egypt, Palestine and East Africa several times. To satisfy ourselves the cement was tested by the P.W.D. and was found to comply with B.S.S. except in expansion. Thereafter, its use was confined to mortar and mass concreting.

The second consignment from Egypt was "drummed" and was fairly satisfactory, although one never knew until the drum was opened what brand to expect, Rapid-Hardening, Quick Setting, etc., etc. The use of this cement was then confined to mast foundation work.

The Ministry of Supply advised that the last consignment was being manufactured in Italy, but it finally arrived in paper bags from England, straight from the kilns; at last we had a cement with the manufacturers' name on the bag and all of one colour and texture. This was an important point, as different brands of cement can alter the colour of terrazzo work considerably.

Storage, Transport and Staff

These headings are grouped together as they were all affected by operation "Bludgeon" which took effect after the commencement of building work. The main R.E. Store stocks in Nairobi were sold by Disposals, and the staff disbanded, which was a hard "blow". One could no longer rush into R.E. Stores to find items that were unobtainable in the civil market. The only storage space available was in C.O.D. Nairobi where an *ad hoc* organization was set up. The Staff, consisting of a civilian Stores officer, a storeman and clerk, dealt with a high tonnage of stores, larger than any other branch of the Command were dealing with at the time.

For example the figures given by "Q" Movements on 19th May, 1952, were D.C.R.E., A.W.S., 610 tons; C.O.D., 409 tons; S. & T., 74 tons.

Transport was cut to the minimum by "Bludgeon" and after considerable agitation the G.E. was supplied with three Ford 15 cwts. for site work. These vehicles had seen better days in World War II and were constantly breaking down many miles from recovery aid. The African civilian drivers did not like the work and were replaced at frequent intervals. Generally their driving did not comply with good practice and all site staff agreed that the vehicles and drivers had a most wearing effect on the human system.

A permanent detail of three tonners was supplied over a period to transport cement, reinforcing steel and electrical stores, etc., to the site. These carried empty containers and irate staff back to Nairobi after breakdowns of 15 cwts. Fords. Transport of steel sections from the C.O.D. store to the steel firm in Nairobi and the fabricated steel to site was carried out by crane and low-loader borrowed from the Air Ministry Works. Dept.

As with the other branches of the Army in East Africa, Engineer Staff at G.H.Q. was cut considerably by "Bludgeon". From February, 1952, until August, 1952, a quantity surveyor was not available; this delayed clearance of measurements, abstracts and final bills.

Survey work on sites was carried out by a Sergeant draughtsman who received his initial instruction in theodolite work from the A./C.R.E. This work, both trying and intricate, was well done, despite difficult circumstances caused by lack of staff and transport.

The site staff consisted of the D.C.R.E., three military Clerks of Works, one storeman and an African typist. The typist armed with a dictionary, English to Swahili, kept pace admirably with Works Orders framed in highly technical terms.

Heating and Ventilation

Only the Army buildings were designed for mechanical ventilation; quite a number of revisions were made and some existing work had to be altered, but fortunately alterations had been confined mostly to the Plant rooms.

The supply and installation of H. & V. equipment was originally put to tender in Nairobi and as only one tender was received by the C.R.E., War Office permission was requested to accept this. War Office refused acceptance, and the "trunking" was therefore re-designed to be "nested" for shipment from the U.K.

The "trunking" then arrived and a new tender, for installation only, was accepted. This resulted in a year's delay in installation and as far as could be seen there was no appreciable saving on the original single tender.

Weather

According to guide books on East Africa the "rainy" seasons are quite distinct: the "long rains" and the "short rains". By experience it was felt that those headings were not quite correct as more man hours were lost through the "short rains" during construction in 1951–2, than the "long rains".

The "short rains" commenced on 17th October, 1951, the sites were waterlogged for three weeks and work was stopped for eleven days; the "long rains" commenced on 22nd April, 1952, the sites were waterlogged for four weeks but no work was lost through rain by day. While efforts were made to cope with the water that poured into every excavation a very small two-stroke pump was produced by the contractor. The W.D. produced two No. 4 Pumping Sets, but these were returned to store, hurriedly, after they had "seized up". The cable crypts were then pumped out by the Army Fire Service and the remainder was left to the Contractor, who returned with his "two-stroke", and natives who "baled" out by hand.

Building Works

Asian tradesmen were hard workers, seven days a week, ten hours a day with few stops for food. Very few had a good basic knowledge of their trade, a case in point being the aluminium roofs to the R.A.F. Transmitter Building. The fixing of aluminium to a conical roof is not easy work even in the U.K. Several Asian plumbers looked at sketches on site, of the welts and seams required, but were not seen again. One man stayed and was instructed on site and made a good job of a difficult task.

There is a great need for a system of apprenticeship and technical education. A high standard of work was produced by masons and carpenters, but it was evident that this standard would only be maintained by strict supervision. The normal tradesman generally had no idea why bond was used in walling or why "grounds" were used behind skirtings and architraves. The greatest difficulty was experienced with plumbers, the City Council of Nairobi has a system whereby a firm is granted a licence when a member had satisfied examiners in his trade. Unfortunately, the employees were not required to be licensed, so one very harassed man had to be responsible for all work carried out on his behalf.

Native labourers were unpredictable, some excavated 40 cu. ft. of rock with a pick and shovel in a day, others were extremely indolent, but all were unreliable in their working days. It was quite common to lose 50 per cent of the labour strength without warning. This happened before the "rains" when the native returned to his village to till and plant his garden, or more probably to watch his wife do so.

The maximum number of men employed was on the R.A.F. Transmitter site during February–March, 1952, being 105 tradesmen, mostly Asian, and 260 labourers, all African.

SUMMARY OF COSTS, KNOWN TO DATE

Preliminary Works		£
Roads, Fencing and Water Supply		15,000
Main Buildings	£	
R.A.F. Transmitter	88,746	
Army Transmitter	49,131	
Army Receiver	20,000	
R.A.F. Receiver	10,000	
		167,877
Guard Accommodation		17,252
Excavation of Cable Routes		12,252
Test Huts on Cable Routes		3,889
Mast Foundations		38,705

Conclusions and Lessons Learnt

Administration and Staff

All works staff for this important job had to be selected from the local engineer staff available in East Africa. This had two disadvantages, first that it entailed fairly frequent changes in staff due to expiry of overseas tours, and secondly, the C.R.E. staff was drastically reduced owing to other changes in policy, and in consequence much administrative work which should have been done by the C.R.E.'s office was thrown on to the D.C.R.E.

Stores

For overseas contracts all proprietary articles should be inserted in the Bill of Quantities as "prime cost" items. Insufficient time was allowed in the tender period for contractors to find out what certain technical items were or what they cost; this led to delays and claims by contractors.

Technical Matters

The use of P.C.P. as a wood preservative was believed to have attracted swarms of bees. In the Receiver Buildings, three colonies were removed from the roof spaces only two months after roofs were completed, although the adjacent guard accommodation roofs which had been treated with creosote were not affected.

Bush rats were a problem, as they were attracted by the housing offered in the cable tunnels, wiring and ventilation ducts and the roof spaces. In this type of country open ceilings would be a better proposition. The cellulose covering to various cables also provided food for rodents. Rats were discouraged from entering the buildings by burning down the bush and grass at frequent intervals and by keeping cats on the establishment.

The Receiver site access road which was on a black cotton soil foundation for the whole of its length, approximately 4 miles, stood up to heavy traffic for two years without requiring major repairs. There were two reasons for this: firstly that the foundation was properly drained, and secondly that sufficient water was used when laying the murram carpet to ensure proper compaction.

The outstanding feature of this project was the complete absence of mechanical equipment on site. These works totalling over £360,000 were completed without the use of a compressor, bulldozer, hoists or any of the common appliances one expects to see nowadays on any civil engineering or major building project.

Scaffolding was a maze of "wattle" poles secured by odd lengths of wire or cordage. The objections and protestations of the English supervising staff were scorned, however, by the local tradesmen.

To conclude this paper, the appreciation of the R.E. staff is recorded of all work done by the architects in London, the contractors in Kenya, and the local tradesmen, all of whom have contributed towards providing buildings which are not detrimental to the very pleasant countryside.

It is the author's wish to thank the C.R.E., Lieut.-Colonel Godfrey, R.E., for his permission to read this paper and to all members of the staff who helped in the preparation.

The Suez Canal

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

DE LESSEPS' masterpiece has figured so prominently in the news that it may be interesting to trace briefly the history of the earliest attempts to provide a waterway between the Mediterranean and Red Seas.

The pioneers in this field of endeavour always planned to use the Nile route up to the Cairo region and thence to excavate a canal to reach the Red Sea at Suez. It appears that the first enthusiast was King Sethos I of Egypt (1300 B.C.), a doughty opponent of the Libyans, Syrians and Hittites. Sethos dug a canal running from the Nile near Zagazig below Cairo as far as Lake Timsah near Ismailia. It followed a depression in which the present Sweet-water Canal flows, and branches served to irrigate the surrounding land of Goshen. A subsequent prolongation southwards from Lake Timsah is said to have quite changed the character of the Bitter Lakes. It is possible that this extension reached to Suez itself. Remains of the channel between the Nile and Lake Timsah were discovered by the French in 1798 and are still visible in places. This section was about 60 miles in length, 150 ft. in width and 16 ft. deep, and boats took four days to pass along it.

The Sethos Canal fell gradually into disuse, and no further plan to connect the Nile with the Red Sea seems to have been made until King Necho, who ruled Egypt some 600 years before the Christian era, tried to re-open the old waterway to Lake Timsah and perhaps for some distance southwards. Herodotus records that 120,000 Egyptians perished while engaged on this work, and that Necho abandoned the undertaking because he had been informed by an oracle that the Persians, whom he greatly feared, might benefit from it. The oracle proved correct, for the Persian King Darius I completed the canal to Suez before another century had passed, commemorating his achievement by erecting monuments to the west and south of Lake Timsah and at Shallufa and Suez. Still later, under the Ptolemies, the canal was improved and locks were built at Suez.

Once again, however, the waterway fell gradually into disrepair, and during the first century before Christ most of it silted up. Then came the Roman occupation of Egypt during which the Emperor Trajan (A.D. 98–117) restored part of the canal and reopened it under the name of "Amnis Trajanus" or "Trajan's River". Little more is recorded about it until the Arabs conquered Egypt in A.D. 646. The Caliphs then decided to connect the Nile with the Red Sea by water in order that surplus grain could be transported easily to Arabia, and with this end in view, they restored the ancient canal to Suez. After the eighth century, the canal again became unserviceable. The Arab descendants of Fatima, the daughter of the Prophet Muhammad, were far too busy establishing their new city of Cairo to take much interest in artificial waterways. It is said that they called the city "El Kahira" (the victorious) because, at the hour when the first foundations were laid, in A.D. 969, the planet Mars (Arabic "Kahir") was crossing the meridian.

Thereafter, for several centuries, no one troubled to revive the Suez Canal scheme, although the Venetians once thought of constructing a canal through the isthmus in order to recover some of the eastern trade which they had lost owing to the increasing popularity of the sea route round the Cape. Louis XIV of France considered a similar project, and in later years it was revived by Sultan Mustafa III of Turkey and by a Mameluke prince called Ali Bey. Nothing came of these ideas; but in 1798 Napoleon Bonaparte arrived in Egypt and, with characteristic energy, caused some preliminary canal works to be undertaken and sent his Chief Engineer, Lepère, to survey the desert between the Mediterranean and the Red Sea. Lepère made a very serious error in his calculations. He stated that the level of the Red Sea was 33 ft. above that of the Mediterranean, whereas actually the difference is small. This mistake induced Napoleon to abandon the scheme for a canal, and the traces of earlier work soon became buried deeper and deeper in the desert sand as decade followed decade.

In 1825, a British engineer named Alexander Galloway, who had been for several years in the Egyptian service, proposed to Muhammad Ali Pasha that a navigable canal should be dug from the Nile to the Red Sea. As usual, no action was taken, but the fact that the proposal was made shows that the idea had not been completely discarded. Five years later, Captain F. R. Chesney of the Royal Artillery, while surveying in the Isthmus of Suez, discovered the error in Lepère's calculations and formed the opinion that a canal connecting the Mediterranean and Red Seas would need no elaborate locks and would offer no great engineering difficulties. His report was duly noted, but again no steps were taken to proceed further with the matter.

The year 1834 is memorable in Egypt because it saw the arrival of Ferdinand de Lesseps, a young French diplomat who came from Lisbon to join the French Consular Service in Cairo. De Lesseps made a study of Lepère's canal scheme and Chesney's report. The scheme appeared to him to offer enormous possibilities, both political and commercial, but it was obvious that serious competition might be expected in the near future from road and railway traffic. In 1838, De Lesseps met Lieutenant Thomas Waghorn of the Bengal Pilot Service and late of the Royal Navy, who had been responsible for developing the overland route through the Isthmus of Suez. Passengers and mails arriving by sea at Alexandria were carried eastwards in boats along the Mahmudiya Canal to the Rosetta branch of the Nile and thence southwards up to Cairo. A service of two-wheeled horse-drawn vans then transported them across the desert to Suez. Each van held six persons and they set out every two or three hours. Sixteen mail stations were established along the route at 5-mile intervals. Food and sleeping accommodation were available at these places. The supremacy of this system of road transport, however, seemed likely to be challenged in 1834 when Thomas Galloway surveyed for the first railway in Africa, a line from Cairo to Suez. Naturally, De Lesseps was bitterly opposed to any such innovation. Some materials were collected at Alexandria, but they got no further, and so the immediate prospect of railway competition was removed.

Chesney's discovery that no great difference of level existed between the Mediterranean and Red Seas was confirmed between 1841 and 1847 by Linant Bey, a chief engineer, and by other experts. A proposal made by Thomas Galloway and his brother John that Cairo should be connected by rail with Suez as early as possible was supported by Lord Palmerston who considered that a canal in French hands might be a menace to proper communication with India. Nevertheless, the canal scheme was preferred and De Lesseps went ahead with his preparations. A Suez Canal Company was formed in 1854 with the approval of Said Pasha, the Viceroy. Excavation began on 22nd April 1859. Said Pasha undertook to meet many of the current expenses and to provide 25,000 workmen, while the Company was to pay and feed these labourers and to arrange for their relief every three months. Water-supply presented a serious problem. Until the Sweetwater Canal was completed in 1863, most of the water had to be sent forward on camels.

March 18th, 1869, was a red letter day in Egypt. Then, for the first time, water from the Mediterranean flowed into the nearly dry and salt-encrusted basins of the Bitter Lakes, parts of which were more than 30 ft. below sea-level. The portion of the canal from the Bitter Lakes to Suez offered no great obstacles. Any fear of the effects of railway competition had already been removed, for a line from Alexandria to Cairo which had been opened in 1856 had been extended in 1858 to Suez without attracting much traffic. Yet this extension proved very useful during the later stages of the Indian Mutiny when 5,000 British troops passed along it on their way to reinforce the army in India. The line was dismantled in 1877. The canal was then in full operation and the railway had become redundant.

The official opening of the Suez Canal by Napoleon III on November 17th, 1869, was attended with much pomp and ceremony. The work had cost about £19 million, of which nearly £13 million were paid by the shareholders and the remainder by the Khedive. Never was money better spent. The voyage from London to Bombay had been shortened from 12,548 to 7,028 miles, and although only 435 vessels passed through the 104-mile length of the canal in 1870, the total in 1875 had risen to 1,500. That was the year in which Disraeli (Lord Beaconsfield) wisely purchased for the British Government 177,000 of the Khedive's shares, thus acquiring two-fifths of the entire stock. Disraeli paid £4 million for these shares. In 1937, their value was £100 million.

When the writer made his first passage through the canal as a small child in 1882, the waterway was so narrow that ships could pass safely only in certain places and the trip might occupy anything from thirty-six to forty-eight hours. The younger ship's officers used to amuse themselves by throwing biscuits at the Arab boys running alongside. How different were the conditions in 1935 when the writer made his twenty-third and final passage in a powerful speedboat which covered the 60 miles from Suez to Ismailia in eighty minutes. Many of the ships were then ten times larger than those of 1882, and their number was five times greater. The original canal had been steadily widened and deepened. As early as 1885, for instance, the Directors had decided to widen it along its whole length so that vessels could pass each other easily and the time of transit could be reduced to twenty-four hours. The canal was then widened to 270 ft. at the top, and deepened to 36 ft., at a total cost of £7 million. Since those days, widening and deepening and the remodelling of curves have proceeded without interruption to suit an ever increasing volume of traffic, and before Colonel Nasser blocked the waterway, ships with a draught of 34 ft. could pass safely through. Let us hope that this essential life line between Europe and Asia will soon be in full use once more.

Photo 1.—The R.E. H.Q. Mess (at the far end of the block) as it was in 1861.

Photo 2.—The R.E. H.Q. Mess in 1956, showing the front extension made in 1883.

The RE Headquaters Mess 1 , 2

The R.E. Headquarters Mess

By Colonel J. M. Lambert, O.B.E.

Brompton Barracks

A plan* dated 1756 shows the area now occupied by Brompton Barracks as an open plain with no buildings of any kind on it. The village of Brompton existed at that time, but it did not extend north of the main road. Together with Chatham Barracks (now Kitchener Barracks), which were built in the early eighteenth century, it lay within the fortifications protecting the Royal Dockyard.

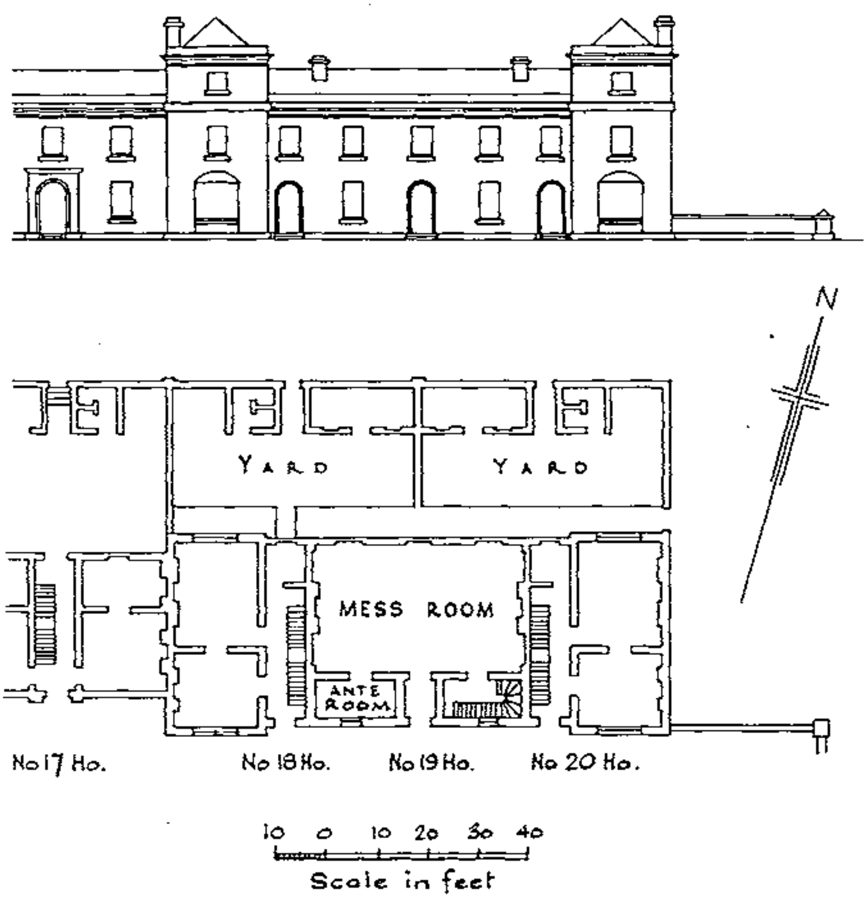
The Brompton Barracks' site is shown, in the 1756 plan, as allotted to two regiments—The "Surrys" and the "Northumberlands". It seems likely that it was used as an assembly area for the troops garrisoning the fort, or possibly as a bivouac area for reinforcements. A track ran diagonally across the area, from the cross-roads in Old Brompton to a gap in the fortifications near what is now the R.E. Park. At that point, where the road now runs, there was presumably a drawbridge over the Ravelin.

In 1804 Brompton Barracks were built and taken over by the Royal Artillery. The earliest known plan of the barracks is dated 1814 and is in the R.E. Museum. It shows the three main blocks substantially as they are today; but the North Square, and also the area behind the South Block, are shown as entirely occupied by stables and gun-sheds. The West Block is marked "Officers' Barracks", but there was no officer's mess. The officers stationed at Brompton used the mess at Chatham (now Kitchener) Barracks; this was probably the building now used as a Sergeants' Mess, and it may well have been a Garrison Mess—for all officers stationed in the fort.

The 1814 plan of Brompton Barracks shows that the north end of West Block (now the R.E. H.Q. Mess) was then identical with the southern end of the same block. The building opposite (now Nos. 9 and 10 Houses) was also identical, and, except that the central doorway has been bricked up, it remains unchanged today. The architect was obviously determined to maintain an exact symmetry in the layout of the barracks about an east-west axis; and this must have caused a good deal of trouble and expense. The escarpment at the north-west corner of the site had, as is not unusual nowadays, been used as a rubbish tip. (In 1940-41 whilst excavating for the underground water tank at the north-west corner of the parade ground, a large amount of rubbish, including a number of old horse skeletons, was dug out). When laying the foundations of the buildings at the north-west corner it was necessary to cut back into the escarpment until solid ground was reached. On the terrace so formed a massive undercroft was built with a vaulted brick arch roof reaching to the original ground level. On top of this was constructed the road in front of the present Mess and part of the building itself.

The undercroft, now generally known as the Mess Cellars, is familiar

*British Museum. A photostat copy is in Gillingham Public Library.



THE RA. AND E. MESS, BROMPTON BARRACKS IN 1814 to most officers because for a great many years, it has been used, heavily disguised with bunting, as a supper room at R.E. Balls.

It is today a part of the Mess premises, but this was not always so. In 1917, following a fire in the North Square, it was re-appropriated as "Mens' dining-halls and kitchens", and it continued as such until 1927, when the present cookhouse and dining-rooms were built in the North Square.

The above peculiarity of site meant also that the Mess building (as it subsequently became) had to have a double-storied basement; and this later had to be extended—as a double-decker—under the present Dining-room and Conservatory. Thus viewed from the front, the Mess, like an iceberg, is largely below the surface.

The "R.A. and E. Mess" 1807–48

On 1st August, 1807, a Mess for Artillery and Engineer Officers was opened at Brompton Barracks. It was called at first, "The New Mess-room at Brompton", and later the "R.A. and E. Mess".

It seems likely that a number of R.E. officers were stationed at Chatham about that time in connexion with the modernization of the fortifications, which were largely reconstructed during the Napoleonic Wars.

Joint Gunner–Sapper messes were not uncommon then and later. There were strong links between the two Corps; both came under the Master-General of Ordnance at the War Office; and officers of both had known their contemporaries at "The Shop" (R.M.A. Woolwich).

The "New Mess-room at Brompton", as shown on the 1814 plan, consisted of a fair sized "mess-room" and a very small ante-room. There was a staircase leading to a kitchen in the basement. The Mess-room, was to all intents and purposes the Large Ante-room of the present H.Q. Mess. Its back wall was that which now divides the Large Ante-room from the Conservatory. In those days it had three sash-windows, and from them there must have been a pleasant view across the river. Possibly at a later date there was a balcony. The back-yard below was similar to that, still existing, behind the remainder of West Block.

There can be little doubt that the Mess-room had been made by knocking the single officers' rooms in No. 19 House into one. But it is not apparent from the plan whether the partition walls were removed on both floors or only on the ground-floor. No. 18 House, now Reception Office and cloak-room, and No. 20 House, now the Small Ante-room, were officers' quarters and at that time did not form part of the Mess.

In 1807 the dining membership of the R.A. and E. Mess was about a dozen officers, of whom six or eight were R.A. and three or four R.E. In 1848 the membership was seventy-four officers of whom ten were R.A., forty-one R.E., and twenty-three were officers of the Honourable East India Company's Engineers; these last being honorary members. It seems certain, therefore, that at some time prior to 1848 the Mess had expanded by taking in No. 20 House to the north (now the Small Ante-room). There is a bricked-up doorway in the north wall of the present Large Ante-room; this would have been necessary, before the present hall was built, to give access from the Mess-room.

No. 18 House to the south (now reception office and cloak-room) was not taken in to the Mess until considerably later.

There is only one item of property now in the H.Q. Mess which is known with certainty to have belonged to the R.A. and E. Mess—a silver-mounted snuff-box, which is still regularly used on guest nights. It is inscribed as follows:—

Brompton Barracks
R.A. and E. Mess
from GEORGE SIM
Bengal Engineers
An Hon^{y} Member
Xmas 1844.

The Independent R.E. Mess Brompton 1848–56

The increase in the number of R.E. members of the R.A. and E. Mess was due to the expansion of "the R.E. Establishment" (later the S.M.E.) which had been instituted at Chatham in 1812.

On 16th June, 1848, Colonel Sir Frederick Smith, who was at that time Director of the R.E. Establishment, made an official request to the Master-General of Ordnance at the War Office for the formation of an independent R.E. Mess at Brompton. He explained the situation in the following terms:—

"I need hardly remark that the officers employed at this Institution are very differently circumstanced to those who are engaged in the current duties of the Corps at the ordinary stations either at home or abroad.

"Here the officers are required to study after, as well as before, the hour of dinner, and that hour requires occasionally to be altered according to the nature of the duties on which the young officers are engaged. For instance, at the season when the pontoon practice is being carried on, the Mess hour is fixed so as to suit the tides, and is generally later than the ordinary Mess hour of other Corps. On the other hand, when 'night tracing' is the subject of instruction, or when a large number of officers are employed in the 'Astronomical Course,' the Mess requires to be fixed at an earlier hour than for the rest of the Garrison, so that in these respects it is desirable that the officers of the Engineers under instruction should be members of an independent Corps Mess, and bearing in mind also the youth and inexperience of the students, I conceive it would be very conducive to their benefit that the whole of the operations and machinery of the Mess in regard to the rules, regulations, and economy should emanate from the Director of the Institution.

"For these various reasons, I beg respectfully to suggest that measures may be taken for making the Mess for the officers of this Establishment and at this station an independent Corps Mess, in the same manner as that of the Royal Artillery is at Woolwich, which is the general wish of the officers under my command."

This request was dealt with remarkably quickly (more so one might think than it would be nowadays). On 8th August, 1848, a Board was assembled to report "what they might consider a just and reasonable arrangement for the division of the Mess property". And less than three weeks later, on 1st September, 1848, the Mess became an independent R.E. Mess under the orders of the Director of the R.E. Establishment. The original copy of the Board proceedings is preserved at the Institution of Royal Engineers, but the inventory of the R.A. and E. Mess property, which was an annexure to the proceedings is unfortunately missing.

1856—The Mess becomes the Corps H.Q. Mess

Before 1856 the title of Royal Engineers applied only to officers. The rank and file belonged to the "Royal Sappers and Miners". The latter's H.Q. and Depot were at Woolwich, but there does not appear to have been an R.E. Officers' Mess there. Probably the Sapper Officers serving at the Depot messed in the R.A. Headquarters' Mess.

In 1856 the other ranks of the Royal Sappers and Miners were amalgamated with the officers of the Corps of Royal Engineers, under the latter title. In the same year the H.Q. and Depot of the Sappers and Miners moved from Woolwich to Chatham, and the Mess at Brompton became the R.E. H.Q. Mess. It has remained such ever since, except for the period November, 1940, to October, 1948, during which time it was established temporarily at Deverell Barracks, Ripon.

A great many additions and alterations have been made to the Mess during the century since 1856. The peculiarities of the site, which have been mentioned earlier, created obvious difficulties in any enlargement of the building; but in spite of—or perhaps because of—these difficulties a Mess of great distinction has been evolved.

The Dining-Room

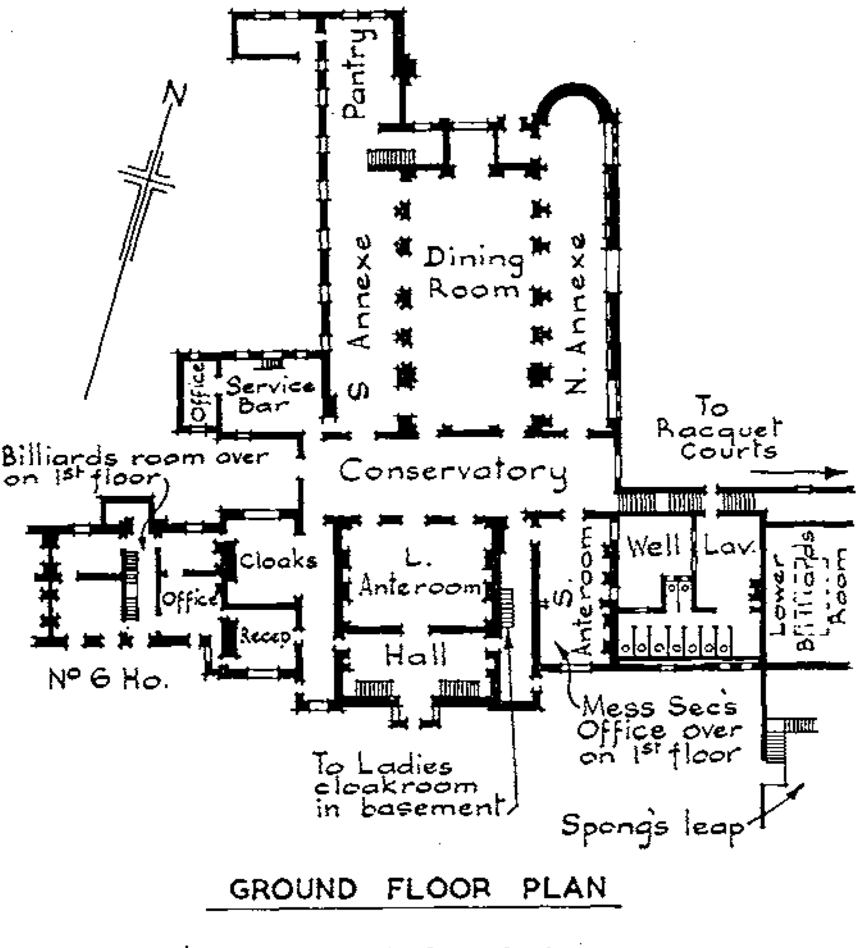
The present Dining-room, exclusive of the North Annexe, was built in 1861 (there had been a previous plan, recorded in the C.R.E. Chatham's "letter book" of 1857, to build a dining-room on the north side of the Small Ante-room.) The Dining-room as originally built consisted of only the central part of the present room. What is now the South Annexe was then divided into three—a pantry at one end and a servery at the far end; and between them there was an alcove in which the band played during dinner. The North Annexe was not built until a good many years later.

At the end of the Dining-room there was a gallery to which ladies were admitted on Guest Nights. This rather medieval custom seems to have gone out of favour by 1890, for in that year the gallery was removed. According to the Corps History the gallery was at the eastern end of the Dining-room; but it seems in some ways more likely to have been at the western end, in the recess. There was until lately a door leading from this recess into the garden and this would have enabled the ladies to reach the gallery without going through the Mess.

In 1874 the Dining-room was largely destroyed by fire. The roof, where the fire broke out, was entirely destroyed and the room, which according to the Chatham *Gazette* was "fitted up in a most handsome manner" was gutted and its fitments ruined. It was feared that the fire would spread to the remainder of the building, and all furniture, plate and wine was carried outside. The *Gazette* records, with a touch of envy, that "the wine when laid out in a nearby field covered near an acre". The repairs to the dining-room, which were covered by insurance, cost about £1,000.

The North Annexe was built in 1887–8 to the design of Captain H. W. Renny-Tailyour, Assistant Instructor i/c Workshops. The pilasters, now painted over, are of grey marble; their Corinthian capitals were originally gilded.

At various times the North Annexe has been curtained off from the main Dining-room, and has been used as a reading-room and as a card-room.



R.E. HQ. MESS, BROMPTON BARRACKS IN 1956

Before 1939 it contained a number of marble or bronze busts. One of these was an eighteenth century bust of Vauban, the great French military engineer, and was the oldest war trophy possessed by the Mess, having been taken from the French Engineers' office at Antwerp in 1814. Its present whereabouts are not known.

Shortly after the North Annexe had been completed, the three rooms in the South Annexe were thrown into one, and the present servery and lift-room were constructed.

Of the portraits in the Dining-room the most striking is that of General Gordon by Val Prinsep. It represents Gordon as a Mandarin and wearing the famous "Yellow Jacket" (now in the R.E. Museum). This had been bestowed on him by the Emperor of China whose forces, called the "Ever Victorious Army", Gordon had commanded. This army, trained and led by European and American officers succeeded under Gordon's leadership in crushing the Taiping Rebellion of 1864. At that time Gordon was aged 31 and a brevet major. The frame of the portrait bears the Chinese names of victorious actions against the rebels.

The portrait of Lord Kitchener was painted by A. S. Cope, later President of the Royal Academy, and was exhibited in the Royal Academy in 1900. The artist had originally intended to paint Lord Kitchener standing beside his charger, and for many years the outline of a horse's head and forelegs could be seen on the right of the picture when the latter was viewed from a position near the middle of the room. This effect disappeared when the picture was cleaned and revarnished in 1950, but it will probably reappear one day.

H.R.H. The Duke of Cambridge was Colonel-in-Chief of the Corps from 1861 to 1904: the impressive portrait of him is by Herkomer the eminent Victorian artist. The other royal portraits in the Dining-room are not originals; those of King Edward VII and King George V were copied from State portraits by Sir Luke Fildes; those of Queen Victoria and the Prince Consort are excellent copies, by Kobervin, of the well known paintings at Windsor Castle by Winterhalter. The portrait of H.M. The Queen which has lately been hung in the centre of the east wall, is a copy by Denis Fildes, of his original painting commissioned by the R.A.O.C. H.Q. Mess.

The portrait of Lord Napier of Magdala is an original by Lowes Dickenson. The keys which Napier is holding are those of the Tower of London, of which he was Constable. The portrait of Lord Heathfield is a copy (by Miss Kate Morgan) of the well-known picture by Sir Joshua Reynolds in the National Gallery. Lord Heathfield, then Sir George Eliott, was Governor of Gibraltar during the siege, and this picture shows him holding the keys of the fortress.

The sofa commonly known as "Gordon's throne" was taken by General Gordon (then Captain Gordon commanding 8th Company R.E.) at the fall of Pekin in 1860. A contemporary account states that during the burning of the Emperor's Summer Palace the troops were allowed to keep such articles as they could rescue from the flames. This remarkable piece of furniture came from the throne-room of the palace and was presented by Gordon to the Mess. Its cushions are not the original ones.

The recess at the west end of the Dining-room is now open to the main room, but this has not always been so. Originally, as mentioned earlier, it may have contained a gallery. Later it was for many years screened off by a low curtain. After 1950 it was for a time completely walled off and the portrait of Field-Marshal Burgoyne, who is generally regarded as the "father" of the Corps, was then hung centrally between those of Gordon and Kitchener. This considerably altered the appearance of the room and opinion was divided on its merits. The general verdict was that it improved the room at night, but that by day it made that end of the room too dark.

The Dining-room curtains were supplied by the Ministry of Works in 1949. The material, which was a good deal better than was normally obtainable at that time, had been specially woven for the Argentine Government; but owing to a difference of opinion on tariffs on meat imports, the export licence for the curtains was cancelled—to the benefit of the Mess.

Until some time in the 1920s the Dining-room was lighted by three chandeliers and, on guest nights, silver candelabra on the tables. There is a sad story of how this form of lighting came to an end. A guest, who was a director of a firm which made electric fittings, offered to modernize the lighting of the Dining-room. This offer, which was made during dinner, was accepted in the mistaken assumption that it was a gift. Shortly afterwards the firm installed the three existing central lights, and a sizeable bill was presented to, and paid by, the Mess.

During the 1939–45 war, Brompton Barracks was taken over for a time by the Navy, and at one time 600 naval ratings were quartered in the Mess Dining-room. Luckily the floor, which is a very good one, was hardly at all damaged, and the building generally was well looked after during its naval occupation.

The Conservatory

At the same time that the Dining-room was built, the gap between it and the old mess building was bridged over and given a "green-house" roof. There was a tiled floor, palms in tubs and, in the middle, a fountain (this last used to play on dance nights until comparatively recently). The present barrel-vaulted roof and timber flooring were constructed in about 1934. This transformed the old and rather Victorian conservatory into a very fine room, which seems, nowadays, to have superseded the Ante-room as the centre of gravity of the Mess.

Before the last war the walls of the Conservatory were hung entirely with big-game trophies. Some of these deteriorated badly whilst in store during the war, and in any case they were by then of interest to only a small and diminishing number of people. So in 1950 the heads were removed and pictures hung in their place.

The "Alamein Picture" which hangs in the middle of the west wall, was commissioned by the Mess as a memorial of the 1939–45 war. It was painted in 1951, by Terence Cuneo, who was given descriptions of the action by eye-witnesses. The artist's underlying aim, most successfully achieved, was to convey a scene of the loneliness and isolation with which the Sapper is faced in this kind of operation. The burning flail-tank in the background is one of the original "Scorpions" used for the first time on that occasion. The "flail" was driven by an auxiliary motor which, with its R.E. driver, was in a small lightly armoured box outside the tank. But there was no lack of volunteer drivers. The red "tracer" shown going overhead from the rear was fired by our machine guns to help the assaulting troops to keep direction.

On either side of the Alamein picture are portraits by celebrated artists. That of Sir Henry Lawson is by Orpen; that of Sir George Fowke is by Sargent. This latter is probably the most valuable picture in the Mess, since Sargent, though he lived in England, was an American subject, and his pictures are highly valued by collectors in the United States.

On the wall opposite, there is an interesting picture, painted in Gibraltar by Samuel Carter and dated 1783. This picture was, until 1950, in the R.E. Museum. The main figure in the painting is Sir George Eliott (later Lord Heathfield) Governor and Commander-in-Chief of Gibraltar during the siege; his horse is held by a Moorish groom, and the Rock of Gibraltar forms the background. The figure on the left is, almost certainly, that of Brigadier-General Green, Chief Engineer of Gibraltar throughout the siege. The scene can be assumed to be an inspection by the Governor of the new fortifications then being constructed on the Rock. Eliott had himself been a Sapper, and apparently could not forget it. This had produced a situation (not altogether unknown since those days) between the General and his Chief Engineer; and the picture leaves one in little doubt that the artist realized this. Green's brigade major at the time was a Captain Holloway, R.E., and the following extract from his diary is illuminating:—

"Gibraltar—24th June, 1782. After dinner I mentioned to the General (Green) that I was not so much upon the works with him as I wished. That when I first came to him, the prospect w^ch^ gave me the most satisfaction was the improvement I should get in my profession by being constantly with the Chief Engineer, by w^ch^ I sh^d^ know more of what was going on in our line than any other. Therefore I hoped to go with him in future whenever he went to lay out any work or to take up ground, or anything else that he thought might be of instruction, for otherwise I was at some disadvantages, being constantly with him, and I had no intercourse with my brother officers, nor any conversation with them concerning the works, fearing they should conceive I was echoing his sentiments. He acknowledged the justness of my argument and promised to be as communicative as possible, *but of late the Governor had been so much the C.E. that he was ashamed to let me see it*" (my italics).

It is interesting to compare the figures of Eliott and Green in this painting with their portraits—that of Eliott by Reynolds in the Dining-room and that of Green which is in the Conservatory. The latter portrait is a copy of one by Samuel Carter, and it also was painted at Gibraltar; the whereabouts of the original are not known. Green was later Chief Engineer of Great Britain for sixteen years and had become a General and a baronet before he retired. He died in 1811 and is buried at Plumstead. Eliott, who had become Lord Heathfield, died in 1790 (of apoplexy).

The Large Ante-room

This room constituted the original Mess of 1807. The west wall, now containing three french windows, was then an outside wall, with sash windows.

The oak wainscotting was added in 1932; and was made to match that in the hall, which was formerly in the R.E. Mess, The Curragh, near Dublin.

The present fireplaces were installed in 1954. The former ones were larger and had semi-circular "club" fenders.

The portrait over the south fireplace is of King George VI as Colonel-in-Chief of the Corps. It was painted in 1951 by Commander Denis Fildes. The portrait as originally painted showed the King wearing a field-marshal's sword whereas, since His Majesty is in the uniform of a Colonel Commandant R.E., it should have been an R.E. sword. This mistake was at once noticed by the King when he inspected the finished portrait and the artist made an alteration.

The picture over the opposite fireplace is a remarkably fine portrait by Frank Holl, of Field-Marshal Sir Lintorn Simmons, who at one time was Commandant S.M.E.

The portrait of Sir Aylmer Hunter-Weston is sometimes taken for a de Laszlo, but was in fact painted "under the direction of de Laszlo"—as stated in a note on the back of the canvas. The frame of this picture originally had a beading on which the General's exploits, or some of them, were recorded; they ranged from "Master of the Staff College Drag" to "Commander of an Army Corps on the Western Front". The portrait of Sir William Dobbie is by the eminent contemporary artist, James Gunn.

The Small Ante-room

This was originally officers' quarters (No. 20 House) and was taken over by the Mess some time during the nineteenth century. It was at one time a "ladies' reception room", the door into the Conservatory being screened off.

There have at various times been plans to enlarge the room by throwing into it the adjoining passage. This was considered in 1904 and the plans for it still exist. It was again suggested in 1951, but the idea was dropped after it had been decided to construct the stairway to the new ladies' cloak-room.

The water-colours, borrowed from the R.E. Museum collection, are by Sir John Ardagh whose portrait is in the Large Ante-room. The oil painting above the east fireplace is of the first operational Bailey bridge ever constructed—that at Medjez-el-Bab, near Tunis in 1943. This picture, which is by Henry Carr, is on loan from the Imperial War Museum, as is also the drawing of a pontoon bridge which hangs over the west fireplace.

In the adjacent passage there is a tapestry, of Nazi origin, depicting apparently Hitler's "Greater Reich". This tapestry came to light in 1951 when it was found, addressed to the Mess, in the officers' baggage store; it had been lying there apparently since 1945. The Mess has no record of its origin.

The picture on the opposite wall is on loan from the Imperial War Museum; it represents Sappers constructing an O.P., camouflaged as a tree, on the Western Front in the 1914-18 war.

The lobby at the end of the passage was formerly the telephone room. The Mess Staff then included a "telephone girl" who seemed to be always on duty, day and night, and ran things very efficiently without the aid of a loudspeaker. There was no telephone box and all conversations took place in the hearing of the telephone girl, who must have acquired a remarkable insight into the domestic affairs of young officers.

The room above the Small Ante-room, now the offices of the Mess Secretary, was prior to 1939 the Large Card-room—earlier "The Whist Room". It was of the same dimensions as the Small Ante-room and held six card tables, all of which were commonly in use, at any rate on Guest Nights. Stakes were limited by Mess rules and all winnings and losings had to be entered in the

Mess "Bridge Book", being credited or debited in officers' mess bills. There was certainly one case of an officer (a subaltern) getting a "plus" mess bill.

The small room which is now used for television was also used as a card room. Its door has a spring latch which can be opened only from the inside. The Clerk of Works used to enjoy pointing this out as "the only such in the barracks and an unauthorized encroachment". According to him it was fitted, many years ago, by certain officers whose ideas of card games and "moderate stakes" were not the same as those in mess rules. It seems more likely, however, that the latch had some connexion with the use to which this room was put at R.E. Balls, before the present ladies' cloakrooms were made.

The Entrance Hall

The front door of the original Mess led, through a very small entrance lobby, direct into what is now the Large Ante-room.

The present entrance hall was designed by Captain A. G. Clayton, R.E., Assistant Instructor in Estimating and Construction at the S.M.E. It was built in 1883–4 under the direction of the Officer-in-Charge of Workshops (Lieutenant J. A. Ferrier, R.E.). The staircases, gallery and the north and south lobbies were constructed at the same time.

The oak wainscotting was added in 1922; as recorded by a silver plaque in the wall, it was formerly in the R.E. Mess at The Curragh.

Of the portraits in the hall, that of Colonel Baird-Smith is an interesting example of an "over-painted" picture. The face is that of the original portrait painted when the subject was a young man. The Colonel's uniform has been added later by a very much inferior artist, who also made alterations to the hair. This picture was restored in 1950, the over-painted part having deteriorated badly. The face was in perfect condition and was not touched during the restoration. It is not known who the original artist was, but was thought to be Sir William Beechey by the Baird-Smith family, who presented the portrait. Colonel Baird-Smith (of whom no biography appears in the Corps History) was C.R.E. at the Siege of Delhi, during which three Sapper subalterns (Home, Salkeld and Thackeray) won the V.C. The Siege culminated in the famous action of blowing in the Kashmir Gate, on 14th September, 1857. Baird-Smith wrote the original report which begins, "I feel assured that a simple statement of the facts of this devoted and glorious deed will suffice to stamp it as one of the noblest on record in military history".

Also in the hall is a portrait (by F. Barwell) of Sir Richard Fletcher. He was C.R.E. to the Duke of Wellington (then Sir Arthur Wellesley) in the Peninsular War and was killed by a musket ball at the Siege of San Sebastian in 1813. There is a monument to him in Westminster Abbey (north-west tower) and it is clear from a circular published at the time that the monument was to be considered also as a Corps memorial of the Peninsular War; this probably explains the absence of any such memorial at Chatham.

The two large pictures hanging above the fireplaces are of a classical subject sometimes known as "The Education of Cupid", the figures being those of Mercury, Venus and her son Cupid. Attached to each picture is a plaque stating:—

"These pictures were taken by Lieut. R. Harrison, R.E. from either side of the throne of the King of Oudh in the Reception Room of the Kaiser Bagh Lucknow, when the City was captured by the troops under Sir Colin Campbell in 1858".

Whilst these pictures were being cleaned in 1951, it was discovered that they bore the "Christie's Mark", indicating that they had at some time been auctioned by that firm. An inquiry was replied to, almost by return of post, giving the exact date, in 1858, of the auction, and stating that "since the pictures did not fetch the reserve placed upon them they were withdrawn."

The donor of these pictures, and also of the charming little painting over the north fireplace, later became General Sir Richard Harrison, G.C.B., C.M.G.

The assault on Lucknow was incidentally, the earliest recorded occasion of an Engineer Brigade being formed for an operation. It consisted in this instance of the 4th and 23rd Companies R.E., one company each of the Bengal and Madras Sappers and Miners, and some Indian pioneers. It was commanded by Colonel Robert Napier, R.E., later to become Field-Marshal Lord Napier of Magdala.

In the Gallery above the hall hangs the 1939–45 "War Gallery". The drawings, which are of R.E. officers who held important appointments during the war, are the work of a Polish artist and were drawn mainly from photographs. Also in the Gallery are photographs of Chief Royal Engineers. The 1914–18 War Gallery is now hung in the Gordon Barracks Mess at Gillingham.

The tiger skin on the wall of the south staircase was, at any rate for a time, claimed as a record. It was shot (and also the one opposite) by Lieut.-General Sir Francis Nosworthy (late Colonel Commandant R.E.).

On the wall above the front door there are two fine heads. They are, on the north side, Greater Kudu (Africa), and on the south side, Bara Singh (Kashmir).

Miscellaneous Additions and Alterations

The officers quarters (formerly No. 18 House) to the south, were taken into the Mess premises at some time subsequent to 1857. The rooms on the ground floor were used at one time for the Mess offices.

The domestic quarters of the Mess are contained mainly in the vast double storied basement. It contains innumerable rooms, now mostly unused, and is a maze of dark passages and staircases. It is easy to get lost in. One of the disused rooms is a large laundry. In pre-war days the batmen, who were all old soldiers, lived with their families in the basements of the single officers' quarters. The wives did all their officers' washing—presumably in this laundry.

During the 1914–18 war and up to 1939 the Mess was staffed mainly by women; though the batmen, in blue-tail coats, helped with the waiting at dinner. The number of women on the Mess staff was about forty. In those spacious days, the basement was no doubt a hive of activity.

The "Lower Billiards-room," now a Games room, was built by the Mess in about 1861. The cost of constructing it was raised by debentures. Presumably these were paid off by the Billiards Fund when it had accumulated a large enough balance. The game was then taken a good deal more seriously than it is today, and the annual match with the Gunners (recorded on the wall) was something of an event. On the north wall there is a skull of that rare Himalayan sheep, the Ovis Poli, shot by Lord Kitchener.

The Billiards-room was built on top of an older building marked on old plans "Porter's Lodge". It is probable that, before the present Dining-room was built, the road behind the West Block continued past the Mess to a gate in the north boundary of the barrack area; the Porter's Lodge would have been at or very near this gate. Before the war this building contained a changing room and bathroom for racquets players; and at one time the racquets marker had a quarter there. It is at present used as a quarter for the kennelman of the R.E. Draghounds. In the basement of the lodge there was an entry into the network of underground passages which connected parts of the old fortifications. The passage is now bricked up a short way from the entrance.

The squash courts which adjoin the Porter's Lodge, were built for the Mess in the 1920s. The racquets court, which has always been a Garrison Court, is a good deal older.

The present, or "Upper", Billiards room was until 1939 known as the Mess Library. It was in point of fact the S.M.E. Library, which was a branch of the R.E. Corps Library, but it was always looked on as being part of the Mess—to which it made a very pleasant addition. The S.M.E. Library has since been absorbed by the R.E. Corps Library which was moved from London to Chatham at the beginning of the 1939–45 war, and is now situated in the old Lecture Theatre in the S.M.E. Main Building, originally known as the "Institute" Building.

The rooms below the "Upper" Billiards-room have been used by the Mess at various times—for the Mess Secretary's office, and as a quarter for the Lady Cateress.

At one time there was a curious affair called a "Time Ball" above the Mess. It appears in a plan (now in the Garrison Engineer's office) dated 1897. The ball, which seems to have been of metal, was about 6 ft. in diameter. It was suspended from a gallows, which rose to about 20 ft. above the roof at the south-west corner of the building. It is marked on the plan "Time Ball drops at 10 a.m. Greenwich time daily, except on Sundays".

It is fairly certain that the object of the "Time Ball" was to give the time to ships sailing from the Medway or lying at anchor. Such devices were no doubt common before the days of wireless, and there is a record of one at Deal Castle, presumably for the benefit of ships lying in "The Downs".

The wing wall running at right-angles to the north-east corner of the building was built, almost certainly, as a result of Mr. Spong's adventure. Prior to 1870 there was an iron railing. This railing, which is not visible in the photograph of 1861, was all that guarded the road from the considerable drop beyond, and which is now known as "Spong's Leap". There is in the Mess Secretary's office a contemporay print showing the incident and the newspaper account of it.

On the 15th February, 1870, we are told, a Mr. Spong of Rochester was transacting business in Brompton High Street. When mounting his horse, "a valuable and high-spirited animal", he lost his reins and his stirrups, and the horse bolted, carrying Mr. Spong "at terrifying speed" into the barracks and past the Mess. It thereupon jumped the 6-ft. iron railing, carrying away the top rail, and landed, with Mr. Spong still in the saddle, on the wooden stairway 17 ft. below. Neither horse nor rider was hurt, and the account states that Mr. Spong, after being treated with great kindness by some Engineer officers who came to his assistance, remounted and rode back to Rochester. His remarkable escape created a good deal of interest at the time and during the next few days, we are told, great numbers of people visited the site.

Red Patch

(Continued)

By the LATE COLONEL A. C. MITCHELL, O.B.E.

THE ESCAPE GAME

THE escape game developed very considerably amongst prisoners of war on both sides during the last world war. With us, for all our other activities, it was probably the subject uppermost in our minds, and although the tally of our successes was small we never gave up trying. It was a real interest to offset the monotony of our lives, and it helped to keep us mentally and physically fit. It occupied our captors, too, and prevented them from ever relaxing their precautions. And on such occasions as we did succeed in outwitting them it gave a fillip to our morale. But it is a subject which can only be discussed with a certain amount of reserve. There may be other wars and other prison camps, and it is important that nothing should be said that might help a future enemy to defeat the efforts of British prisoners to escape. What follows, therefore, is limited to matters already known to the Axis authorities, but enough can be said to indicate the variety of the methods employed and even some of the amusing sidelights which occurred.

The game started primitively, with "spur of the moment" attempts on our side and rather casual precautions on the other. But it quickly became an affair of detailed planning and established principles as the only means of defeating greatly increased precautions. It was an instance of the old struggle between attack and defence, with each side in turn in the ascendant, but with the initiative generally in our hands. Lacking the mentality which wanted to escape, our captors could rarely get inside our minds on the subject: they could never entirely prevent attempts at escape, but only try to close in succession the various "stable doors" we opened for ourselves. Their attitude would vary between a friendly desire for a gentleman's agreement—few restrictions if we made no breaks—and an intense, almost hysterical suspicion of our every action. The gentleman's agreement, of course, never worked, but the intense precautions proved exhausting and expensive in guards. With a few Camp Commandants pride was also a factor; and they either took it as a personal insult if we tried to escape or else lost their tempers because the British could outwit them in anything. They could not see it as a game, as we did, and only one Commandant of those we knew said: "It is your job to escape; mine, to stop you."

On our side we started very much from scratch—unfit, unprepared and without experience. We were perhaps not sufficiently "escape-conscious" at first and took time to react to our situation. Only later did we realize that the easiest time for escape had been in the initial stages whilst we were still in the battle area. There the custody of prisoners was not our captors' first preoccupation and their measures to guard us were quite elementary. They realized our extreme exhaustion, of course, and appreciated that mere distance and inhospitable country were further safeguards. We did get one or two people away in these early days but, without maps, compasses, reserve food and some other kit than British uniform, escapes were then hardly feasible propositions.

In our permanent camps we again started from scratch, reconnoitring thoroughly, studying the habits of our guards, slowly collecting resources; but precautions were no longer elementary. We were in a land of identity cards and police, where any stranger or unusual action attracted suspicion. Few of us could hope to pass as local inhabitants. The conduct of the battle was not the first concern of the local troops and they could devote far greater efforts and resources to our safeguarding. We were walled-in and wired-in, with closely patrolled and floodlit perimeters. We were frequently mustered and our few possessions were regularly searched. Our guards were sometimes in the proportion of two to every prisoner. An escape therefore became a deliberate operation, with much planning and preparation. Most camps formed escape committees to co-ordinate plans and control common resources, for there might be several plots hatching at one time and they required careful control if they were not to fall over each other. The committee would also organize any mass escape plans contemplated.

For individual or small party schemes we had to consider the following points. Our object was to get as many of the most useful people as possible not only out of camp but also back into British hands. It was this second part which was always the harder: we knew so little of outside conditions and, once out of camp, an escaper was entirely dependent on himself. Yet it was this second part so many individuals considered least: they merely hoped for luck. We had to fix their minds on a definite objective—some specific place to get to—and help them work out every step to that objective. We had also to consider where to make for: some frontiers were nearer than others, but not all touched on friendly neutrals. We did not know what would happen if we reached a neutral country: would we be interned or sent on to British hands? Internment might be better than captivity but was not our real object, since it was not the individual's freedom but his further usefulness which counted. The sea might also be reached, but even if escapers could then steal a boat they would still have a considerable voyage before them. We had also to ensure that "impossible" plans were barred: the few ways out of camp could not be squandered on foolishness. Although our captors never took the affair as a game we had to try and avoid bitterness, reprisals and the unnecessary casualties of a "shooting party". A man had to escape before any alarm was given if he was to get away at all: it was a case of secrecy and surprise against armed force. Again, not everyone who proposed escape was temperamentally fitted to try: it was not merely an outlet for ragged nerves. Our resources, too, were not unlimited. We learnt to make passable civilian clothes, could forge passes and manufacture keys or essential tools: some of us were becoming expert thieves. Yet how primitive were most of our weapons in this private war we waged—scissors, nail files, a hidden claspknife, odd bits of metal tempered and fashioned over the stove: with these and only these we had to do everything. Finally we had to ensure that we did nothing to infringe the principle of the Red Cross or the policy of getting our invalids to proper hospitals: our captors must have no excuse to reduce our all too infrequent food parcels.

Tunnels come to mind when thinking of escapes and we had our share of these. If successful, of course, they allowed a large number to escape, but they took many months to construct. Of seven tunnel attempts in two camps, only one was successful: all the rest were discovered before completion.

There was a certain "barn tunnel", for example, for which a repair patch in a concrete floor had been carefully cut out as a lid over a vertical shaft. The gallery had been driven about 80 yds. and had only another 20 yds. to go to a small hollow beyond the perimeter. A hose of oil-soaked cloth fed fresh air from a primitive pump to the working face. For light there was string wick in bottles of hair oil or medicinal paraffin. Then, one night, it was discovered quite accidently by a guard stepping on the dust-camouflaged lid which rocked slightly. It was prised up and the guard ran for the sergeant. An officer and a posse of troops arrived and there was much chattering. A man was sent down the tunnel to investigate, but was long in returning: he had found the tunnellers' reserve chocolate! A few days later the two senior British prisoners were haled before the Commandant: they must have known about the tunnel, they were told, and their crime lay in not reporting it!

Another tunnel was soon afterwards discovered elsewhere in the camp—not so accidently, we felt, as a party of guards marched straight to it one afternoon and caught the team at work. Our captors were developing rather a tunnel complex and were not long in finding a third which had been making good progress. That one infuriated them as it was lit by electricity off the hut supply: to tunnel was bad enough but to use Axis electricity in the process was to add insult to injury. We did not seem to be lucky over tunnels, but yet another was begun. Equipment was improving: a better air-pump had been contrived and the air hose was now of jointed cigarette tins or the cardboard cores of toilet paper rolls. Work went rapidly and it only remained for the party to break through into a root field outside camp but, as the selected night brought torrential rain, the break was postponed for twenty-four hours. In that time, however, disaster came: the rain caused the collapse of the thin covering of earth at the exit and the hole was seen by a farmer. But not until a guard had crawled through from the exit and come up beneath a certain dormitory floor were our captors able to find where the tunnel started.

On some of us being moved to a new camp, tunnelling started from a vegetable patch we cultivated in a high-walled courtyard. The gallery was aimed to come out in a disused slit-trench a little way beyond the sentry walk outside the perimeter wire. As events proved, it should have been carried farther but we had to think of the season and time was short. The attempt was made one August evening when we were allowed to watch a cinema film in the courtyard. As it grew dark eleven men entered the tunnel and its entrance was closed behind them. An hour later the film started and, as we had hoped, the nearest sentry moved a little along his beat to watch it. The sound of the "talkie" would drown any noise of breaking through into the trench and getting away. A signal buzzer had been rigged from the gallery to a room from which watch could be kept on the sentry's movements. An "all clear" buzz was given; the thin crust of earth between the gallery and the trench was broken and the first man crawled away. One by one, as signals were given, seven men got clear, but then sentries changed and the new man stayed beside his box within a few paces of the tunnel exit. No more "all-clear" signals could be sent: the film ended and all was quiet. But there were still four men in that gallery, their retreat blocked as night guards patrolled in the courtyard, their advance covered from within a few paces by a sentry. An impromptu mouth organ concert was started in a near-by room to make some noise but this was soon silenced by the guards. A diversion elsewhere in camp would only turn out the entire garrison. But watch continued in the dark from the window and about one o'clock the sentry began to pace up and down. A buzz sent the eighth man crawling out: he was seen or heard and the sentry fired. The man got clear but the game was up and all the normal hubbub of alarm began. The sentry found the hole in the trench and was just stopped from firing blindly into the gallery where the last three men crouched. These were led away to the "cooler" and the remainder of the camp was mustered for counting and recounting until 4.30 in the morning. But eight men had got away and the leading ones had had up to three hours start before the alarm had been given. Seven were, however, recaptured next day but the eighth was at large for a week. Lying up in some near-by hills till the first local excitement was over, he then made a wide detour for the frontier. But there he got into extremely steep mountain country and within a thousand feet or so of the summit—and sanctuary—he collapsed exhausted and was discovered. Our captors thought highly of that tunnel when they examined it: it must have been the work of a qualified mining engineer, they said. "Not at all", we replied, "but we are all clever here." And perhaps the eighth man had got away on a bicycle, they suggested. "Perhaps we can make bicycles too," we told them, and they anxiously searched for possible bicycle parts.

Tunnels were slow and at best a long-term policy. Parallel with them we organized individual, "over the wall" attempts. We had an early success with an officer who had been brought up in the country and could talk the language really well. For weeks he was coached for "gallstones" until the camp staff was convinced he was ill and sent him to a civil hospital. He slipped out from there, changed into prison-made civilian clothes sewn inside his battledress, bought a railway ticket and was soon drinking beer at the expense of some British Consul in a neutral country. But we did not like the idea of breaking from hospital lest it should prevent our genuine cases from getting there. Six weeks later we tried a threesome—two who could speak the language to go dressed as Axis officials, the third as their girl-friend. The Axis uniforms were excellent but the girl friend was astonishing. She was young, dark and slight, and had a carefully cultivated girlish voice. Her skirt and matching handbag came from a tartan rug: she had a plain jumper and Burberry, a scarf over a shingle of several months growth, stolen silk stockings, shoes with fancy openwork fronts, all the etceteras and even lavender water on her clothes. The party had scaled three compound walls on its way out of camp when it was surprised by a patrol, but the girl friend later made an excellent principal girl in our Christmas Pantomime.

Three weeks later a lone man slipped out and was cleverly stoodged for on musters all next day. With twenty hours start we hoped he was well clear, but the police of a distant town rang up to say they had him. The duty interpreter must have had a nasty ten minutes with the Commandant after that as he had thrice reported us all correct that day. Two evenings later we tried again with two officers dressed as camp guards. Carrying a ladder, they crossed the guards' barracks and, in the guise of camp electricians, pretended to test one of the floodlights at this less closely watched part of the perimeter. A sentry hailed them and approached: they jumped from the ladder over the wire: the sentry fired and got one man in the thigh. But the other got clear and, changing from his uniform into workman's dress, eventually reached a town near the frontier. Prospecting near there for possible crossing places, he was asked for his papers and interrogated: the game was up. He went to thirty days solitary confinement, but later tried again and succeeded. Meanwhile, with two breaks in forty-eight hours, things in camp were tightened up. All timber likely to make ladders was removed, civilian mackintoshes were confiscated, additional surprise musters were introduced and stoodging became more difficult. But we were certainly keeping our captors busy.

We realized that the main difficulties lay outside camp and that we must have contacts. One officer struck up an acquaintance with a workman who came about camp and learnt that he was thoroughly disgruntled with the war and the régime. He would help provided he could save his own skin and put something in his pocket besides. On a certain day the officer could follow him out of camp, dressed as his assistant, the day depending on a particular sentry—fiancé to the workman's daughter—being on duty at the gate. The daughter would be there to hold the lad in talk. Later there would be a proper mufti suit, railway tickets and the daughter as escort to her aunt's house near the frontier, where the officer might lie low until he could be smuggled over. It was what we needed—outside help to save escapers from contacts with officials. But it never happened as the officer, with others, was moved to another camp before arrangements could be completed.

Our last adventure in that particular camp was not an escape but a straight drama of treason and brandy. The camp authorities had occasionally tried to persuade individuals to turn traitor and help the Axis but, as far as we knew, without success. One day, however, a young airman prisoner was summoned to the Commandant's office, politely received, offered a chair and a cigarette and gently pumped for information by an Axis Intelligence Officer. Talk veered round to prison life. It was bad luck to be a prisoner but no doubt the airman realized that there was much to be said on the Axis side, apart from the fact that it was winning. He might even sympathize a little. ("Have another cigarette, my good man.") How would he like a trip to the capital, with a friendly soldier as companion, with civilian clothes, money and whatever he liked? He must think it over and they would talk again. Back in his compound, the airman sought out the British chaplain. "This concerns the British Empire as much as it does your soul," he was told. "You'd better see the escape committee." The committee thought hard. It might be a plant but the airman was no fool, and if he would go through with the scheme he might learn much valuable information. The risks were, of course, explained to him, and also the possibilities. He decided to take the chance and we began to pump him up for his next interview—with answers to questions he might be asked, further questions to his new "masters" and how to play idiot boy if the going got too hot. Some days later he was taken to a house a few miles away. A very attractive woman appeared, speaking perfect English: brandy was dispensed. She was sorry for all prisoners. Was he married and how long had he been away from England? She knew just how he felt and he must have some more brandy. "The girl was a peach but I stuck to the brandy," he told us later. The Intelligence Officer then appeared. What about this idea of a holiday, then of learning a few simple things? The airman would be put into a neutral country as if he had escaped, and when he got back to England he would only have to write a few letters. The lad kept his head, despite the brandy; of course, there were risks, he said, and he must have more time to think. He was allowed to bring the rest of the brandy back to camp with him, and when we heard his story we pumped him up again. He had little to fear and when he got home he could tell his story. He was not sent for again, but on the day some of us left for a new camp he also left, ostensibly to go as batman to the new General's camp. What happened, we never knew; but the affair had been quite a thrill and some of us would gladly have been in the airman's shoes—no, not just for "peach brandy".

At our new camp we had to start the escape game all over again. We were in a large, three-storey building surrounded by high courtyard walls and then an outer perimeter of barbed wire. We were forbidden the ground floor after "Lights Out", and altogether the place offered far fewer possibilities than had our former camp. But we were not long idle and six weeks after our arrival we tried to get an officer out in a large barrel the camp staff had left about and whose lid we had suitably altered. The barrel was called for one evening: the officer was quickly inside and it was rolled to the gate by four batmen. But to our horror, as we watched, the lid partially opened and, although it was hurriedly closed again, one of the guards must have noticed it. The barrel was rolled into a store and when the lid was removed the occupant found himself looking up at half a dozen bayonets. Barrels were "off", but we turned our attention to the window-bars of a ground floor lavatory which gave access, across a barbed wire fence, to an inner courtyard where a sentry patrolled. But if one could pass the courtyard it would not be difficult to climb over the guards' barrack hut, cross another open space and finally scale the main perimeter wire behind a store hut where there were fewer sentries. Bar-cutting, however, could only be carried out during the day, and then only during the short periods when the courtyard sentry was in the farther half of his beat with his back to the window. We estimated that it would take two weeks of this intermittent work to get out one bar and make a gap through which a slim man might squeeze: each day's cutting would be camouflaged with chewing gum and paint. The attempt was timed for a moonless night and had to be completed by 11 p.m., after which hour we could not use the ground floor. To keep the sentry distracted, a gramophone concert was started in the mess room at the far end of his beat, and he stopped to listen. The final cuts were made in the bar, an officer squeezed through the opening and began to negotiate the barbed wire fence. But then the sentry's conscience struck him and he began to walk back along his beat. The officer could neither go forward nor back, and at three yards range the sentry saw him and raised his rifle. "All right. Don't shoot," the officer said, and the alarm was given. All window bars were thereafter more vigorously shaken on each day's inspection, and all ground floor windows were also heavily wired up in addition to their bars.

Again we were not long idle and a month after the window bar failure we tried to get a foursome out. Next to our kitchen was the camp staff kitchen; and a hatchway, now bricked up, had once linked the two. The plan was to gain access to the camp staff kitchen through this hatchway, go out through the front door of the staff mess beyond and get away at a less closely patrolled portion of the perimeter. The preparation was difficult, however, as we could only work at that hatchway by day when there were often camp staff about.

In addition, there were two sentries outside different kitchen windows within a few yards, whilst the Commandant's office was directly overhead. The hatchway brickwork joints were, however, carefully cleared of their mortar and the hatchway camouflaged by a large noticeboard to whose presence the camp staff had first been made accustomed. Probing the cleared joints had led the team to believe that the brickwork was only a thin skin on our side of the hatchway, and that the rest, on the staff side, might be an open recess. But this, of course, could not be confirmed beforehand. The foursome included a sailor with a compass and a camp-made chart of the ocean disguised as a golf course: if they could get to the coast and steal a boat they hoped to sail to neutral territory. Dummies were prepared for their beds, and for weeks each of the team had tried to persuade the night patrols that he always slept with the bed sheet over his face. The attempt was made on another moonless night and, although it failed, it gave the camp the best party it ever had. The first brick skin was quickly cleared from the hatchway, but then a second was discovered. Time was short and there were two sentries within earshot, but by 3 a.m. the second skin had been cleared and one man crawled through to explore. As he reached the mess door an excited guard rushed in: at the same time shouting was heard in our part of the building. The officer managed to slip back through the hatchway and the four tried to withdraw to their rooms. But the hunt was on and pandemonium reigned. The night patrol had found a dummy: lights switched on everywhere: whistles blew: dogs barked: the entire garrison rushed to its posts. Sounds were heard in our mess room, which the escapers had reached in their retreat, and a fat sergeant rushed in: fearing attack in the dark, he fired twice at random. That, at least, was his later story; but the escapers stoutly maintained that he had switched on the lights, aimed deliberately when they had their hands up and hit one of them. Meanwhile, the fun elsewhere had become fast and furious. How many dummies were there? Every bed was searched. An officer looked out from a second-storey window, and ping! a bullet bedded itself in the ceiling above his head. Only fools looked out of windows on such occasions, of course, but this was rather a special one. Another officer, also watching from a window, rather foolishly dropped a small piece of mortar on a stationary guard below and it bounced off his helmet. This was mutiny! attack! But nobody knew exactly what was happening. There was noisy excitement on Floor "A" where the first dummy had been discovered, a battle evidently in progress in the mess room, and guards being stoned in the courtyard. Then some trees rustled in the night breeze and a jumpy guard, thinking we were up there too, swung round and aimed into the branches. It was a miracle that most of the garrison did not shoot each other that night. Muster sounded and we stood about being counted until half past six in the morning. Altogether a wonderful party but such a disappointment as the plan had seemed to hold great possibilities. Meanwhile, the four officers, doing their thirty days "cells", protested vehemently at having been shot at and an inquiry was held. Each side stuck to its story and the officers were finally accused of perjury. There was also the desperado who stoned gallant guards in the execution of their duty. Both matters were taken before a higher military tribunal: there was defending counsel and everything was fairly conducted, but of course all were guilty. The four perjurers were given three years imprisonment but the stonethrower three years and a half: stone-throwing was evidently the more serious crime. Then all except nine months of each sentence was remitted and as it had taken nine months to bring them to trial they were promptly dismissed—to one of the bad boys' camps.

We had a Brigadier in camp who suffered from a terrible itch to be free. He had one plan after another until he became a bane in the lives of the escape committee. First he thought to get out dressed as a batman on the rubbish fatigue. Then he had the idea of a rope and hook fixed to the roof guttering which would let him swing clear of a barbed wire fence; but the guttering was so flimsy and the drop to concrete below so considerable if anything broke that the committee forbade the scheme. Next he tried to cut a hole in a concrete wall but made so much noise that he was quickly discovered and given a spell of confinement. This finished, he made a hole in a bricked-up first-storey window from which he could slide down a rope and try to scale a fairly easy outer perimeter gate that was not always closely watched. This plan, however, depended on the near-by sentry being occupied opening the inner courtyard gates for the night patrol: it might take him thirty seconds to do this and if the patrol was well bunched at the gates it could not see a man dropping from a window. Weeks of watching had failed to give the right conditions, and night after night the Brigadier had had to cover up his work and scuttle back to his own bed in another wing before the night patrol got there. Then one winter night there was perfect bunching at the gates: he was down his rope and quickly over the perimeter gate. But the patrol found his dummy and he heard the "Alarm" before he was a mile from camp. He had astonishing luck, however: in workman's dress he caught an early train to the nearest town: in the station lavatory there he discarded his workman's clothes and emerged looking like a Ruritanian Army bandmaster. On the strength of this magnificent turn-out he was able to buy another ticket and eventually reached a frontier town. A cab drove him to its outskirts to prospect but there for some unaccountable reason he got into argument with the cabby. A policeman appeared but as neither could understand the Brigadier's "Ruritanian"—it was actually Urdu but he tried to convince them it was Croat—he was invited to step along to the police station. Confronted there by an interpreter, the Brigadier felt that things were getting uncomfortably warm; and when he thought he heard the words parachutist and spy he had visions of being summarily shot, so blurted out that he was an escaped British prisoner. In his marvellous fancy dress they would not at first believe him, and not until the telephone had got busy were things sorted out. He went to the usual thirty days confinement and a bad boys' camp.

On the subject of mass breaks there were plenty of wild ideas but few really feasible plans. A mass break differed from an individual escape in this most important respect that it involved no secrecy but rather mass defiance of our captors. And that defiance was unarmed against considerable numbers of armed and easily excited guards. Surprise was, of course, aimed at in all such plans, but at best it could only have been very temporary. The odd sentry might have been rushed, but the whole of a large camp could not get away in the matter of a minute or so and camp garrisons did not take long to turn out. Even if it might be assumed that the first phase succeeded and that all or most prisoners got away from a camp, what then? There was a widespread alarm system throughout the country to put the army and police on the alert.

Hundreds of prisoners could not all have had adequate civilian clothes and the majority would have been quickly rounded up. From experience of the temper and excitability of some of our captors there was no knowing what savage reprisals might then have been taken against prisoners recaptured in such circumstances or whether they might lay themselves open to be summarily shot for "attacking" a sentry or on some other charge. In one camp we did go a certain way with a plan for a mass break of some seventy prisoners on one of the walks we were periodically taken—by a sudden rush at our flanking guards on some deserted country road—but in the end even its most ardent supporters admitted its impracticability. We also had plans for a forceful break-out should the Allies ever get close to the camp. But unless the Holding Power is on the verge of collapse and no longer cares whether it keeps its prisoners or not, a mass break from any camp more than a few miles from an easily crossed frontier—and few camps were thus situated—is simply not a feasible proposition. Not one-tenth of the escapers are likely to get clear and there will be far too many dead men.

Searches have been mentioned and it may be well to say something more about them. They were supposed to be thorough and to come as a surprise, but they were rarely either. One was searched, of course, on leaving a camp or arriving at a new one, and such searches could be more exhaustive than others: one's few possessions afforded little scope for concealment of any but the smallest articles. One also expected a general search of the whole camp after any attempt at escape, but one could be ready for that and little of worth was ever found on such occasions. The old hands at the game were, in fact, rarely off their guard: their treasures were well hidden and always hidden until actually required. In the making of kit, maps, tools and the like there was a risk of being surprised, but this could be greatly reduced by a system of outlying scouts—unobtrusive gentlemen who lounged at windows or commanding corners and who blew their noses or gave some other sign if danger appeared. Our captors were unimaginative, too, and some did not really care. A thorough search of the entire structure of a large camp was virtually an impossibility. In some camps prisoners stood to their bunks with their possessions laid out before them, and searchers came round each in turn; but if the job had to be got through in a day or a morning it soon degenerated into something very perfunctory. In other camps prisoners would be mustered in the yard while guards searched the empty dormitories, each guard accompanied by a prisoner to avoid any risk of pilfering. On one such occasion an officer accompanying a guard pulled out his cigarette case and offered a cigarette. (It was generally a sound tactical move if done in privacy.) Taking one, the guard asked if the case was silver and was told it was. "But don't you know", he said, "that today we take all silver things. You yourself must afterwards be searched in the yard and this will be found. Come with me." The two returned to a room which had already been searched and the case was solemnly hidden beneath the occupant's blankets. "That will be safe as we do not return here. You can now be searched and later you will ask this man for your case." It is wonderful what an English cigarette can do.

On the subject of hiding places one must speak with reserve. There were mobile and immobile caches, of course; those on one's person or in one's kit for journeys, and those in the structure or area of the camp itself. Most of our losses came from mobile caches as search of these could be more thorough. One must have variety in the types of hiding places, however, so that the discovery of one does not compromise all others of the type. One must also have several baskets for one's eggs, so that risks are spread and one misfortune does not entail the loss of too many treasures. Soap, toothpaste, brush handles, books, gramophone records, photo frames, shoe soles, suitcase linings, playing cards, certain games, the collars and shoulder straps of battledress were all known to camp staffs. Yet there were others if one thought of them, and some of us came through many searches with treasures intact. One officer and the few contents of his tiny room were turned inside out for fifty minutes by five trained searchers but, though frequently very "warm", they discovered nothing. The obvious was sometimes the best. The same officer preserved, for emergencies, a half bottle of "John Haig" through two years of searches by the simple expedient of putting it in a medicine bottle, labelling it "Linament Internal Scots" and leaving it in full view on a shelf. Not once did his captors think of taking out the cork and smelling it, until one night a small aspirin bottle of the stuff was found on a recaptured escaper. Most buildings offer great possibilities—stairs, door or window frames, lock housings, tiled or wooden floors, lavatory cisterns, walls, fireplaces or overmantles that lift out complete to conceal larger articles like dummy heads. Furniture and fixtures can often be "processed" without marking. We were not long in acquiring small stocks of cement, lime, plaster, distemper and paint, stolen in tinfuls and useful for repair work if we explored through forbidden walls or ceilings. And our experts could cut keys for most doors.

Such in its briefest outline was the escape game as we played it, but sufficient may have been said to indicate some of the problems on the one side, the methods of dealing with them on the other. It was never an easy game yet, despite failures, it rarely slackened. Many others played it, too, in other lands and other camps, and often more excitingly than we did. But it was much more than just something to do with our leisure. A strong escape spirit in a camp was a sign of high morale. For many, too, escaping was a definite driving force and purpose, if not in getting away themselves, at least in helping fitter men to do so. And in its co-operative team-spirit it was perhaps one of the best factors of prison camp life.

(To be continued.)

Left to right: Major L. G. Williams, Lieut.-Colonel A. R. Currie, Lieut. W. T. Collins, Major K. C. Fenton, Major P. H. G. Hamilton, Colonel R. Trevor Smith (all R.N.Z.E.)

A pair of silver candelabra was recently presented by the officers of the Corps to their brother officers of the Royal New Zealand Engineers.

The formal presentation took place on 22nd September, 1956, during a regimental dinner at Linton, where the New Zealand School of Military Engineering is located.

It was not possible for an Officer of the Corps to be present, and the presentation was made, on behalf of the Corps, by Colonel R. Trevor-Smith, O.B.E., Colonel Commandant of the Royal New Zealand Engineers, to the Chief Engineer, Lieut.-Colonel A. R. Currie D.S.O., O.B.E., R.N.Z.E.

The candelabra was suitably inscribed "in memory of past mutual achievements and as a token of abiding friendship and esteem."

The function took place during a triennial training conference attended by officers of the Royal New Zealand Engineers, both Regular and Territorial, which ensured a large company being present.

Accepting the candelabra, Lieut.-Colonel Currie expressed the thanks of the officers to their brother officers of the parent Corps and to their many Royal Engineer friends and war-time associates. He said that the Association of the New Zealand Engineers with the Royal Engineers went back to 1840 when the first Royal Engineer officer, Lieut. Lugard, arrived in New Zealand, and to 1845 when New Zealand soldiers served as Sappers under Captain Marlow, R.E., in the Maori wars at the Bay of Islands. This association has been maintained in various ways up to the present time.

In his letter giving details of the presentation, the Colonel Commandant expressed his grateful thanks to the officers of the Corps, and stated that he had no doubt that this token of esteem will cement the sound friendships that already exist between the Corps and the Royal New Zealand Engineers.

Presentation Of A Pair Of Candelabra To The Officers Of The Royal New Zealnd Engineers By The Officers Of The Royal Engineers

Correspondence

DEVICES OF WAR

From Lieut.-Colonel L. V. S. Blacker, O.B.E., T.D.
Cold Hayes,
Liss,
Hants.
12th January 1957.

To Editor, *R.E. Journal.*
Sir,

Your reviewer, in his recent notice of "Devices of War", was good enough to make some kind remarks about myself. He, quite correctly, referred to me as a Guide.

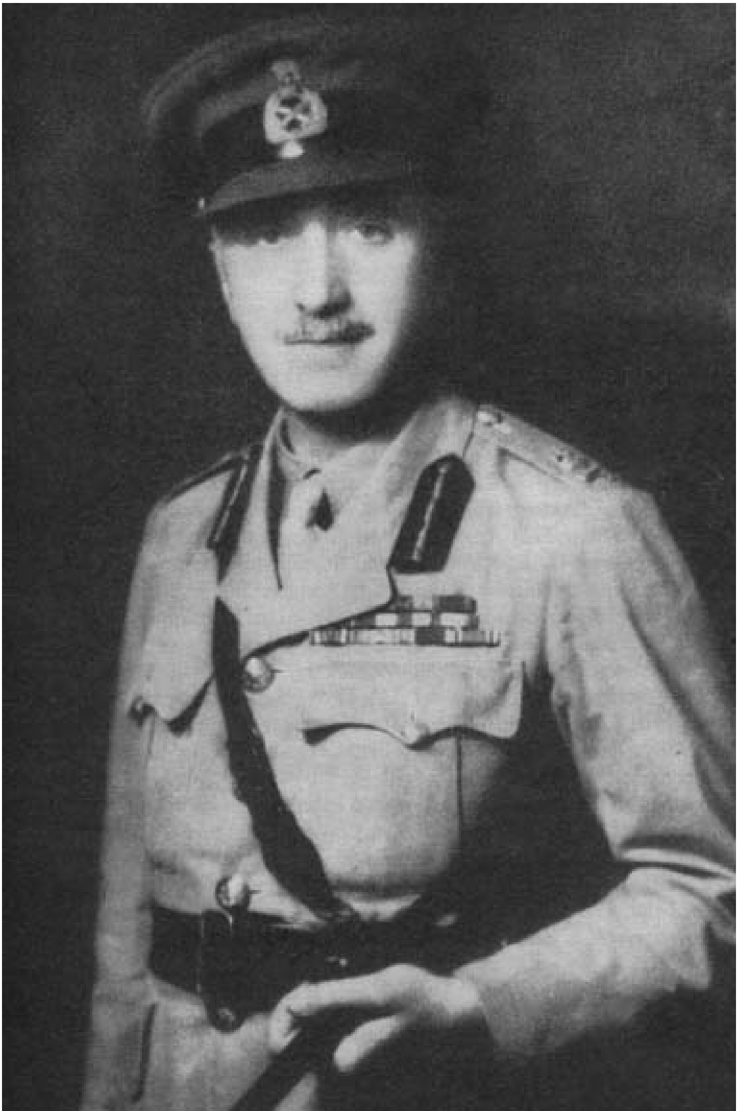
All the same, I feel it a duty to the Corps of Royal Engineers to tell your readers that the four "Spigot" weapons of the 1939/45 War, the "Bombard", the anti-submarine "Hedgehog", the P.I.A.T. and the "Mortar, recoiling Spigot", alias the "Petard", were the culminating fructifications of a germ implanted in 1904/05 by four attested Sappers of the East Anglian Royal Engineers. Their leading spirit was, afterwards, Lieut.-Colonel G. L. Ritchie, Royal Scots Fusiliers; another was, rather later, the Right Reverend the Bishop of Blackburn and another myself.

The mortar then developed was inspired by the wooden, or bamboo weapons used by the Japanese in Manchuria. Closely resembling it were those mortars for jam tin projectiles extemporized in Flanders, notably by the Royal Bombay Sappers and Miners. The "hollow-charge" of the P.I.A.T. owed something to the instruction imparted to us of the Cavalry and Infantry, in Peshawar in 1909 by the Subaltern of No. 3 Field Coy. Bengal Sappers and Miners,* who told his hearers about the "Monroe" effect and plastic H.E.

The wheel came full circle in 1944, when that subaltern became the Commander of the 79th Armoured Division, whose Royal Engineer Assault Regiments in Normandy used, and expressed their gratification with, the "Petard", and its "Flying Dustbin", the fourth of this series of low velocity but very high powered weapons. The "Petard" of the A.V.R.E. was, indeed, almost a much enlarged P.I.A.T. The Army owed, as so often, a debt to the support of the unconventional, by the Royal Engineers.

Yours faithfully,
L. V. S. Blacker.

*P.C.S. Hobart, who later transferred to the R. Tank Corps.



Lieut General Sir Gordon N Macready bart,KBE, CB CMG DSO MC

Memoirs

LIEUT.-GENERAL SIR GORDON N. MACREADY, BART., K.B.E., C.B., C.M.G., D.S.O., M.C.

(The following Memoir is mainly taken by permission, from *The Times* of 19th October, 1956.)

LIEUT.-GENERAL SIR GORDON N. MACREADY who died at his home in Paris on 18th October, 1956, at the age of 65, had a distinguished military career and after his retirement from the Army held a number of important posts in the Control Commission for Germany.

Gordon Nevil Macready was born on 5th April 1891, the only son of General Sir Nevil Macready, the last Commander-in-Chief of the Forces in Ireland, who was created a baronet in 1923, and grandson of William Charles Macready, the famous actor. Educated at Cheltenham and the Royal Military Academy, he was gazetted to the Royal Engineers in 1910. Throughout the 1914–18 war he saw active service in France and Belgium, he was mentioned five times in dispatches, and was awarded the D.S.O. and the M.C. In the latter stages of the war he was A.A. and Q.M.G. of 66th Division and in the Supreme War Council at Versailles, having been given the brevet of major in 1917.

He was one of the first British officers to enter Berlin, arriving well ahead of the British diplomatic representatives, to serve as A.A.G. of the British Military Mission. Then as chief of the Polish Police Mission in 1919–20 he organized the police force of the revived Polish State. Regimental duty at home followed for a time, but having graduated from the Staff College, he was posted as a G.S.O. III to the War Office. Very shortly, however, he was again selected for special duty and in 1926 he began, as assistant secretary of the Committee of Imperial Defence, seven of the busiest years of his life. For his services with this Committee he was appointed a C.M.G. in 1932.

His grasp of the wider problems of strategy was strengthened by a course at the Imperial Defence College and he rejoined the War Office staff in 1934 as a G.S.O. I. He was appointed Deputy Director of Staff Duties two years later and remained at the War Office until 1938. During this period he had much to do with the modernization of the Army.

His next post was even more important, for in 1938 he was sent to Egypt to advise on defence measures and spent two fruitful years there, which proved the value of his services after the campaign in the Western Desert had begun and he was back in Whitehall as Assistant Chief of the Imperial General Staff. There he worked with immense energy in equipping the Empire forces, and since much material was supplied by the United States, he was soon well known to the higher American military authorities.

In the summer of 1942 he was appointed Chief of the British Army Staff in Washington and remained there until his retirement from the Army in 1946 with the honorary rank of lieutenant-general. His period of office in Washington was marked by an ever growing integration between the British and American military staffs, and this result may be largely attributed to his energy and drive. He was appointed a C.B. in 1942 and created K.B.E. in

1945. In 1946 he was appointed a Colonel Commandant R.E. He was also a Commander of the American Legion of Merit and of the French Legion of Honour.

Retirement from the Army meant to him only a change of status and work. His father had died in January, 1946, and he had succeeded to the baronetcy. In the spring he went to Germany as Civil Commissioner for Hanover and in October, under the reorganization scheme, he became British Commissioner for Lower Saxony. When the British and American zones of occupation in Germany were fused he was appointed joint chairman, with an American colleague, of the new bizonal economic organization, and in 1948 added to his duties by becoming Regional Commissioner for North Rhine-Westphalia. He succeeded Sir Cecil Weir as economic adviser to the British Military Governor in Germany in 1949 and finally retired in 1951.

He married in 1920 Elisabeth, the younger daughter of the Duc de Noailles, and the baronetcy devolves upon his only son, Mr. N. J. W. Macready, who was born in 1921 and married in 1949 Mary, the only daughter of Sir Donald Balfour Fergusson. There are two daughters and a son of the marriage.

G.S.M.B. writes:—

Lieut.-General Sir Gordon Nevil Macready, with whom I served as A.D.C. for a period of over six years in Egypt and Germany, was a man of remarkable character and during all my service on his staff never did I hear an angry word. He had a wonderful brain and could quickly grasp the point of any argument. He took an interest in everybody who worked around him, which won their affection as well as their respect.

General Macready was a good all round sportsman, an excellent horseman, shot and a keen fisherman. His golf was above average and his tennis certainly improved after his marriage to Lady Elisabeth Macready, who was tennis champion of France.

In Egypt we enjoyed some wonderful duck shooting and it was quite usual to find over fifty ducks credited to his bag. During his service there he became a keen horticulturist and his Egyptian gardener won the cup for exhibition giant chrysanthemums.

In Germany one perfect fishing holiday will always linger in my memory when he was given Reich Marschall Goering's train to take him for an expedition from Frankfurt to Bavaria, and the luxury of a bathroom on the train gave food for thought.

In Frankfurt, General Macready made a most valuable contribution to Anglo-American relations. He liked the Americans and the Americans liked him with his quiet sense of humour and his generous co-operation.

General Macready was respected by all the foreign embassies, which was proved by the many countries who sent representatives to his memorial service. A grand soldier, who after his retirement wrote a book, *In the Wake of the Great*, which covers both world wars and gives an insight into the high planning behind the scenes.

A touching tribute was received from his driver in Indo-China who read of the memorial service and paid respect to his gallant chief, and his entry into the "Valhalla of the Great".

His death at the age of 65, is a sad loss to his friends all round the world.

He was buried at Maintenon in France.

COLONEL SIR GERALD PONSONBY LENOX-CONYNGHAM, KT., M.A., F.R.S.

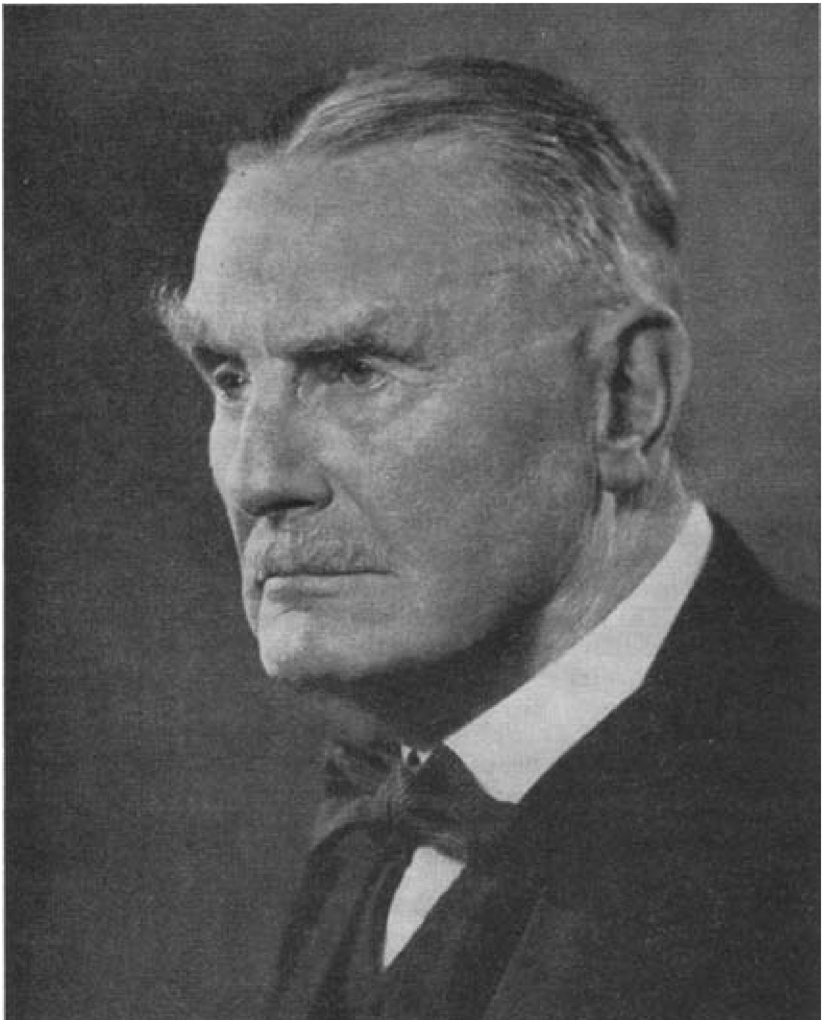
GERALD LENOX-CONYNGHAM, was born at Moneymore, Londonderry on 21st August, 1866, the fifth son of Sir William Fitzwilliam Lenox-Conyngham, K.C.B. He was educated at Edinburgh Academy and the Royal Military Academy, Woolwich, passing out at the head of his batch, and was commissioned in the Royal Engineers in September, 1885. The first part of his long and active career was in India: the remainder in Cambridge. Even after retirement in 1947, he remained almost to the end of his life on 27th October, 1956, the valued counsellor of his friends. Throughout he was sustained by Lady Lenox-Conyngham, daughter of Surgeon-General Sir A. E. Bradshaw, K.C.B., whom he married in 1890; she and their daughter Enid survive him.

Soon posted to India, he joined the Survey of India in 1889 where he was engaged on astronomical field-work for the next dozen years. From 1894–6 as partner to Burrard (later Sir Sidney Burrard, Bart., K.C.S.I., F.R.S.), his senior by five years, he was on deputation out of India conducting observations for the precise longitude of India, then embarrassingly in doubt. These two great men—for they were of great stature and of equally notable ability—became and continued fast friends: but they ever remained to each other just "B" and "C". The value of the longitude of Karachi which they found was closely confirmed thirty years later by observers of the 1926 International Longitude Project, who had manifold advantages of developments, such as wireless telegraphy.

Local arrangements for two solar eclipse parties visiting India early in 1898 were entrusted to "C". At one of the camps he met Newall, later Professor of Astrophysics at Cambridge, and formed with him a friendship which greatly influenced his later life. Then came some years of precise latitude observations, from which deflexions of the vertical are derived—the *direction* of gravity. "B" was then seeking the cause of these and previously found deflexions: extra observational evidence, in the form of the *force* gravity was needed.

Thus in 1902 a gravity survey was planned. "C" was delegated to Europe to examine, acquire and standardize the best available pendulum equipment: and two years later he brought out to India a set of four brass half-second pendulums. The next four years, during which the present writer was fortunate in being associated with him, saw the foundation of the series of observations which had nearly covered India and Burma before World War II. A great difficulty with brass pendulums under field conditions is temperature determination of the pendulum shaft. "C" went far to meet this by his "dummy" pendulum, whose shaft contained a thermometer. Later he proposed "invar" pendulums: but was dissuaded from their construction by reason of invar's magnetic susceptibility. None the less, subsequent pendulums have usually been made of invar!

It is noteworthy that Burrard's deflexion work was freely admitted by Hayford to have been the incentive for his work on isostasy: and that the gravity survey, initiated by Conyngham, provided, in the Gangetic plain, the first major example of regional departure from the state of isostasy!



Colonel Sir Gerald P Lenox-Conyngham Kt MA FRS

In 1912 Lenox-Conyngham became Superintendent of the Trigonometrical Survey. He was an excellent administrator: a firm but sympathetic and trusting chief. Absence of disorder and steady progress were apparent in offices where he held charge, whether field party or directorate. The onset of World War I frustrated his natural promotion to Surveyor-General; for the services of Sir Sidney Burrard were extended for the duration of the war. Thus Lenox-Conyngham finally left India as Superintendent in 1920, having been elected F.R.S. in 1918 and received the honour of knighthood in 1919.

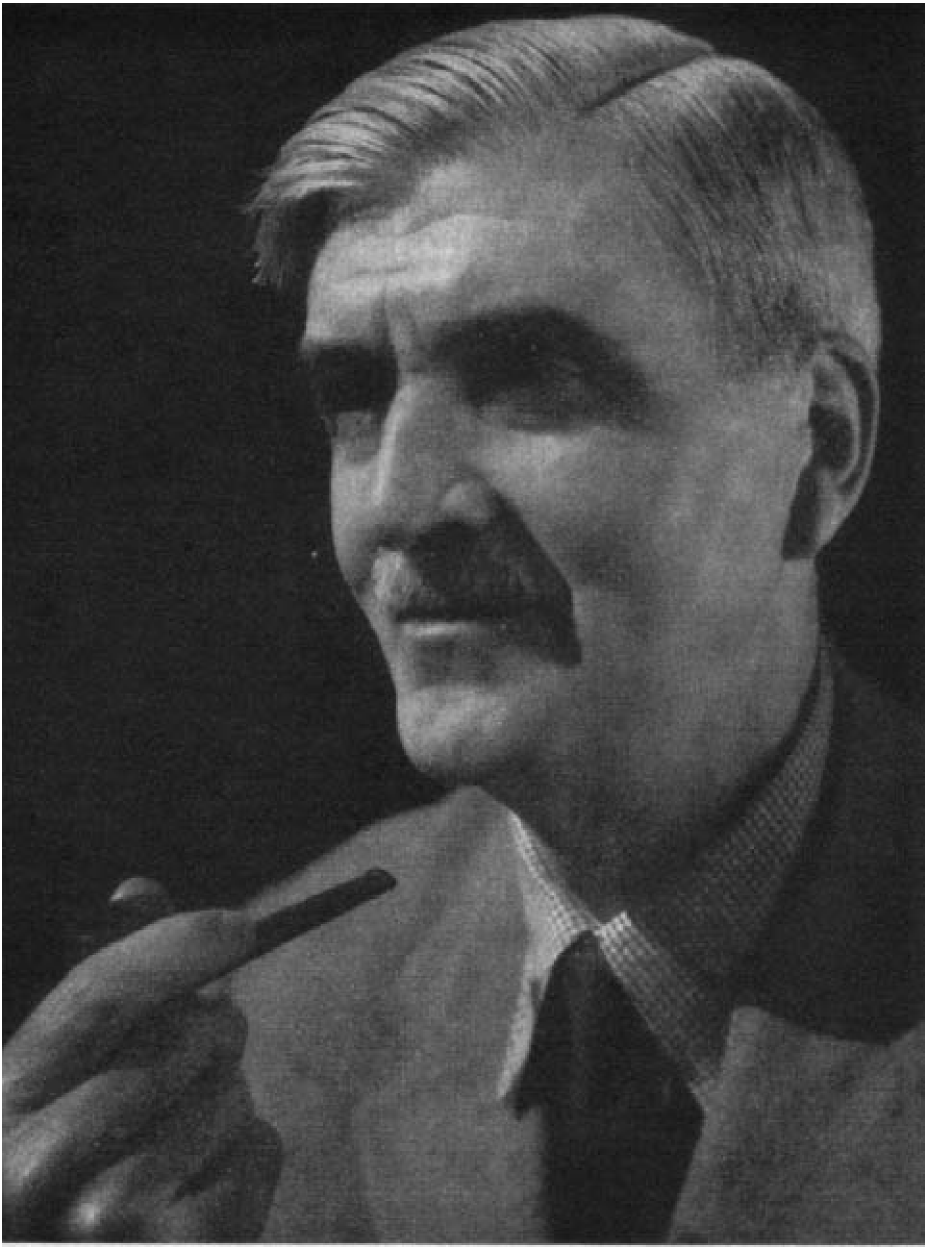
In 1898 Professor Newall had had an intimate view of the then greatest existing practical geodetic organization: and he felt strongly that geodesy, neglected in England, should be promoted: so he urged Trinity College, Cambridge, of which he was a Fellow, to take action. Only last October, at a luncheon given by friends to Sir Gerald and Lady Lenox-Conyngham to mark their joint attainment of the tenth decade, Sir Gerald made a remarkable speech: and he recounted how, after his return to England in 1920, he had received a letter from the then Master of Trinity, Sir J. J. Thomson, asking him if he would accept a Praelectorship in geodesy coupled with a Fellowship of Trinity: and with what satisfaction he assented.

The formation of a School of Geodesy involved especial difficulties for a newcomer to the University; but his charming presence and shrewd sense inevitably prevailed. The School was formed and later in 1931 was expanded into the Department of Geodesy and Geophysics. Geodetic and Topographical Surveying became one of the four subjects for the Geographical Tripos: and the School became the training centre for most of those who later became the principal Survey officers of the British Colonial Empire. Meantime the University created a Readership in Geodesy and appointed Lenox-Conyngham to it, having previously conferred on him the degree of M.A.

During this second career he attended four of the General Assemblies of the International Union of Geodesy and Geophysics: including the first at Rome in 1922 and the sixth at Edinburgh in 1936. He also represented H.M.'s Government at the second and third Pacific Science Congresses, in Australia in 1923 and in Japan in 1926. The inhabitants of Montserrat, Windward Islands, alarmed at the increasing frequency of earthquake shocks, petitioned their Governor to obtain scientific opinion as to their security. So the Council of the Royal Society, consulted by the Colonial Office, invited Lenox-Conyngham to visit the neighbourhood and to investigate the seismic circumstances. He did this in 1936: and gave some account of the situation in a Friday evening discourse at the Royal Institution on 12th March, 1937. He also served on the Council of the Royal Society for periods 1920–1 and 1934–6.

For some twenty years at Dunseverick, their attractive house in Mussoorie, the Himalayan hill-station above Dehra Dun, the Lenox-Conynghams extended much hospitality with much endearing kindness. The same situation recurred at their Cambridge home, Desertlyn in Grange Road: for they soon established a large circle of friends and there was always a welcome for the goedesy students as well as for old students revisiting England on leave. Lenox-Conyngham had become the father of British geodesy. Recently he received the affectionate greetings and congratulations of the International Association of Geodesy: and his passing, inevitable though it be, is a lively sorrow to a wide international circle.

J. de G.-H.



Brigadier Sir Harold J Couchman Kt DSO MC

BRIGADIER SIR HAROLD J. COUCHMAN, Kt., D.S.O., M.C.

HAROLD JOHN COUCHMAN ("Couch"), who died on 30th November, 1956, was the son of the Rev. H. Couchman. He was born on 29th July, 1882, and educated at Haileybury, where his father was on the staff. Passing out of the R.M.A. he received his commission in the Royal Engineers on 18th August, 1900, and on completion of the Y.O.'s course at Chatham was posted to India in September, 1902. He spent several years as Garrison Engineer in Quetta, Loralai, and Aden and then joined the Survey of India in January, 1906. Up to the first World War he was employed almost entirely in geodetic units engaged in magnetic, astronomical, and pendulum work, and continued the gravity investigations started by Sir Gerald Lenox-Conyngham. He was promoted Captain in 1910.

In October, 1914, some eighty Sapper officers, mostly from civil employ in India, sailed from Bombay for England and were distributed among the new units then being raised. Couchman was one of these. During the war he was successively Adjutant 21st Div. R.E., O.C. 98th Field Coy., and C.R.E. 39th Div. R.E. He received the M.C. in 1916, the D.S.O. in 1918, and was promoted Major in 1916.

Soon after reversion to the Survey of India in December, 1919, he was posted as O. i/c Surveyor General's Office. This was a charge in which he was soon able to display his very marked flair for administration. Between 1926 and 1929 he was temporarily transferred to the Mint Department as Deputy Director, Security Printing, at Nasik.

In March, 1931, Couchman, now a Colonel, rejoined the Survey of India as Director, Eastern Circle at Shillong, and after holding the posts of Director, Frontier Circle and Map Publication, was appointed Surveyor-General of India on 1st October, 1933. His tenure was in a difficult period of reorganization after the great retrenchment of 1931, and of changes introduced by the India Act of 1935 and by the separation of Burma. He tackled all these problems with the wisdom and zest of the born administrator, and with the consideration for others which endeared him to those who served under him. No crisis ever disturbed his serenity. His memory was prodigious and he retained it unimpaired to the end of his life. He received his Knighthood in May, 1937, and retired in September of that year.

He married, in 1925, Evelyn Beatrice, daughter of Colonel W. L. C. Baddeley, R.E. During the years after the war they lived in Chelsea, where he was immobilized by a long and crippling illness, borne with uncomplaining patience and tempered by the devoted and unremitting care of his wife.

C.G.L.

Book Reviews

THE CANADIANS IN ITALY, 1943–1945

By Lieut-Colonel G. W. L. Nicholson
Historical Section, General Staff

(Published by Edmond Cloutier, Queen's Printer, Ottawa $3.50)

At Staff colleges and places devoted to military learning certain subjects are spoken of, rather guardedly, as controversial. This means that when they come up for discussion, argument will be hot, but that satisfactory conclusions will be rare. The strategy and grand tactics of the Allies in Italy constitute just such a subject. Colonel Nicholson has, therefore, been a model of discretion in his strictly objective handling of the voluminous material, upon which he has based his book. The list of references, alone, runs into sixty-six pages and includes much information from German sources which is used here and there to mark high points of the narrative. This reliance on factual evidence has resulted in really good military history and the book will be invaluable to the military critics of the future, as well as to Canadians and their comrades-in-arms, who fought in Italy.

Throughout the war the Government of Canada was at pains to secure that their magnificent troops were used to the best advantage and that, as far as military considerations allowed it, they fought together under their own commanders. Yet, when the invasion of Sicily loomed up, there was no hesitation in detaching the 1st Division and the 1st Armoured Brigade from the Canadian Army in England, so that they might gain experience in a major landing operation and represent Canada, in what was certain to be an historic operation of war.

Later on and perhaps less desirably, Canada pressed for and succeeded in obtaining the deployment in Italy of a Canadian Corps of two divisions. This was an embarrassment to the Allied High Command, which did not require another Corps H.Q.— Moreover, shortage of shipping prevented the transport to Italy of the vehicles of 5th Canadian Armoured Division, which had to take over those of the "Desert Rats" instead. This arrangement looked well enough on paper, but proved to be highly unsatisfactory in practice. In spite of these minor frictions, however, the Canadian formations fought with unrivalled gallantry and distinction all the way from the beaches of Pachino in Sicily to the River Senio in the Lombardy Plain, to which the difficult approach along the Adriatic once more belied the description of Italy as "the soft under-belly" of the European fortress.

It was perhaps rather hard that the removal of the Canadians to Holland in February, 1945, deprived them of their share in the final triumph in Italy, which followed only two months later and towards which they had contributed so much.

B.T.W.

THE SOVIET ARMY

Edited by B. H. Liddell Hart

(Published by Messrs. Weidenfeld & Nicolson, 7 Cork Street, W.1. Price 36s.)

Captain Liddell Hart has chosen an opportune moment for the publication of these essays on the Soviet Army, contributed by some thirty writers of international distinction including himself. Between them, they leave their readers under no illusions about the size and power of the Soviet Army.

The standing peace-time army of the U.S.S.R. is, without doubt, the largest that the world has ever seen. About 100 divisions (one-third armoured) are believed to be located west of the Beresina in three north to south Army Groups, whose main bulk is nearer to the Baltic than to the Mediterranean. The H.Q. of the three groups is in

E. Prussia and an advanced guard of twenty-five Soviet divisions is in E. Germany. About seventy-five divisions are held in three more Army Groups, in the Caucasus (H.Q. Tiflis); Central Asia (H.Q. Tashkent) and L. Baikal- Manchuria (H.Q. Chita.) Each Army group disposes of an air army, which can allot a division of 120–240 aircraft to each armoured and rifle division when air support is required. Hardy, rigorously trained and equipped to modern standards, the standing Soviet Army can be fully mobilized in six weeks and increased to over 400 divisions in three months. In addition there are, in Europe, over eighty divisions found by the satellite nations of the U.S.S.R.

On the debit side of the account, there are also some important items. The ordering of the Soviet Army is so tightly controlled at the top, that the initiative of the more junior leaders, from divisional commanders downwards, is stifled in the very places where it is most wanted. This connotes a serious defect in the human mechanism of the command system. In past wars the Russians have, also, been slow off the mark at the beginning of campaigns. The slow start against Finland in December, 1939, and the delayed reaction to the German onslaught in June, 1941, are modern examples of a weakness, which Frederick the Great turned to his advantage in the Seven Years' War. In this nuclear age the opening of a campaign is only less important than the winning battle, so that to be a bad starter is a great handicap.

Far more important than these lesser failings, which training and experience might eradicate, are signs that the various nations of the U.S.S.R. are losing their almost religious belief in Marxist Communism as the panacea for all evils. If such loss of faith became widespread, it would shake the vast Communist empire to its very core and make its huge armies unreliable.

Nevertheless it would be most unwise to discount too much the size and power of the Soviet Army, which are so well revealed in these essays. Indeed many readers of Liddell Hart's admirable book will begin to wonder whether "the nuclear deterrent" and a mere screen of N.A.T.O. divisions can possibly ensure the peaceful co-existence of the Western democracies and the U.S.S.R. It seems far more probable that, until N.A.T.O. can reckon its divisions in dozens, the West will only get peace from the U.S.S.R. on the blackmail terms, which are already being levied. In truth, warfare can be of many kinds and the nuclear deterrent cannot prevent all of them. *The Soviet Army*, which will be read far beyond these shores, may bring this cardinal fact home to the nations of the West and induce some of the laggards to bestir themselves before it is too late.

B.T.W.

THE KING'S AFRICAN RIFLES

By Lieut.-Colonel H. Moyse-Bartlett, M.B.E., M.A., Ph.D.

(Published by Messrs. Gale & Polden Ltd., Aldershot. Price 30s.)

The history of the King's African Rifles has been short, but full of incident. It was only towards the end of the nineteenth century, that the *Darkest Africa* of Livingstone and Stanley and of Speke and Burton, began to take shape as the Crown Colonies, which we know today. Nor was it until 1902 that the local security forces of the new Dependencies were consolidated into the K.A.R., with battalions scattered about East and Central Africa from the Red Sea to the Zambesi.

In his long book of over 700 pages with many maps and photographs, Lieut.-Colonel Moyse-Bartlett traces the origin of the units antecedent to the K.A.R. and then follows the fortunes of the new Regiment from operation to operation and from war to war right up to the end of 1945. Thus this first complete history of the K.A.R. is a long tale of battles, and at the same time a veritable mine of information about tropical Africa.

The author perhaps fails to stress the looseness of the regimental organization of the K.A.R., and to make it clear that the battalions are maintained by their various

Colonies and enjoy an unusual measure of independence. A final chapter bringing the story right up to date and outlining the difficult problems of the future, would have added to the value of his detailed and fascinating study of African warfare.

B.T.W.

BRIDGING THE YEARS

By C. M. Norrie

(Published by Edward Arnold (Publishers) Ltd. Price 21s.)

It is rare that an engineer turns historian; but when it happens, as it does when Mr. Norrie describes the history of Civil Engineering in Britain it makes a book that is always interesting and sometimes inspiring. It traces the history of Civil Engineering as a profession from its birth in this country just over 200 years ago.

The book is at its best in the early chapters dealing with the work of the pioneers to whom the present high status of the profession may be ascribed. It vividly relates their almost fanatical attempts to apply scientific principles then being discovered by an awakening Europe to the early skills and crafts, a motive that may be said to have inspired all their work. One cannot but be impressed to read of natural geniuses, some with the most rudimentary education, who became members of that most elect body, the Royal Society, and thereby brought to their old trade the benefits of scientific knowledge.

Interest, however, is not sufficient to make a good book and this one has its lighter side rendered all the more humorous because of the serious nature of the context. It is difficult to suppress a smile when it describes the first meeting of the Institute of Civil Engineers at which rules were formulated for membership. The founder members, whose ages were between 19 and 32 then stipulated age limits for membership to be 20 to 35 (shortly after extended).

The gigantic status these men achieved in public opinion is well illustrated by the story of John Hawksworth. Faced with cavilling amongst his backers on whether the cost of payment should be met in full, the reader can imagine the shattering impact on the proceedings made by him when he judged the discussion to have proceeded far enough and he stated "What John Hawksworth signs—you pay".

A less desirable feature of the book is an attempt to make it into a text-book, to which some title like a "Concise History of Civil Engineering in Britain" might be appropriate; an impression heightened by the layout of the subject matter and paragraph headings. The book would have been improved if no attempt had been made to cover all the personalities to which Civil Engineering in this country is indebted for the last one hundred years; but to have been content to deal with the epics of railways and the canals more impersonally. The book is extremely readable and of interest to any engineer who is interested in his profession. J.P.F-S.

DUMPY LEVEL WORK

By James Vose

(Published by Cleaver-Hume Press Ltd. Price 9s. 6d.)

This book has been written primarily for the jobbing builder, to show the equipment and methods of levelling by instrument, and in particular to illustrate the advantages of these techniques over the traditional boning rods, straight-edge and spirit-level.

The first chapter is devoted to illustrations and descriptions of several types of level. Unfortunately, the majority of instruments mentioned are somewhat out of date and little reference is made to either the quickset or engineers level which are most commonly used in military engineering.

Subsequent chapters describe the methods of setting up the instrument, common sources of error and how to avoid them, and maintenance, adjustment and repairs. Descriptions of both the target staff and telescopic levelling staff are included.

The chapter on the use of the level in the field describes the method of setting out spot levels, sight rails, running a section of levels and setting out road and drainage gradients. It includes the preparation of a level book by the rise and fall method.

The book finishes with a description of the more modern developments of the Cowley automatic level and Aqualev.

This book is well written in simple straightforward terms and contains sufficient information to enable the reader to carry out minor levelling tasks. However, since it is such an elementary book, it is only considered to be of value to the reader who has had no previous experience of surveying. J.H.G.S.

BRITISH RAILWAY TRACK DESIGN, CONSTRUCTION AND MAINTENANCE

Compiled by a Committee of the Permanent Way Institution

(Published by the Permanent Way Institution. Second edition 1956. Price 28s.)

The first edition of *British Railway Track* was published by The Permanent Way Institution in 1943, and it was intended primarily as a text book for members of the Institution studying for their qualifying diploma in practical permanent way construction. Due to its popularity it was reprinted in 1947, and again in 1950, without amendment to the text.

During the past few years there have been a number of important changes in the construction of British permanent way, notably, the introduction of the new flat bottom track, and the increased use of mechanical plant and appliances. The edition under review has been revised and enlarged to incorporate many of these developments and it covers the entire field of permanent way construction and maintenance.

One of the principal features of this work is the authority with which it is written. Like the original edition it has been compiled by a team of experts co-ordinated by an editor, Mr. R. A. Hamnett.

Although the component parts of current standard military railway track are somewhat lighter than those employed by British Railways, the methods of setting out and the techniques of construction are in many ways very similar. This well written text-book might therefore be considered as a useful supplement to *Notes on Military Railway Engineering*—Part II (Engineering), 1940.

Now that railway construction has become a general Corps responsibility, since it is no longer normally undertaken by units of the Transportation Service, all Sapper officers will find this book both valuable and interesting reading. D.F.D-B.

THE ULTIMATE LOAD THEORY APPLIED TO THE DESIGN OF REINFORCED AND PRESTRESSED CONCRETE FRAMES

By A. L. L. Baker, D.Sc. (Eng.), M.I.C.E., M.I.Struct.E.

(Published by Concrete Publications Ltd. Price 18s.)

For some years there seemed to be little prospect of producing an ultimate load method of designing reinforced concrete frames comparable with the plastic hinge theory for structural steel work. Reinforced concrete appeared to be too complex and brittle a material for similar treatment.

As a result of research work carried out by Dr. Baker and many others over the last few years, Dr. Baker has now felt justified in collecting together in one book the relevant parts of various papers published on this research and applying the ultimate load theory to the design of reinforced and prestressed concrete frames.

The author states that the work done so far on the problems of shearing, buckling and combined bending and direct stress are insufficient, but does not think that future research will greatly modify the present recommendations for design.

The first chapter deals with the determination of the factor of safety and assumed strength of the concrete to be used with this method of design. This is derived from experiment and statistical analysis.

One chapter is devoted to the ultimate strength in bending of reinforced and prestressed beams and another to the plastic deformation of hinges and members.

The last chapter deals with examples and applications of the plastic hinge theory. It is not considered, however, that this will be of much use to the average designer.

This book requires very careful and detailed study in order to understand it fully. It is not considered suitable for the general reader, but might be of interest to advanced engineering students from a theoretical standpoint. J.M.

THE PRINCIPLES OF MECHANICS

By Heinrich Hertz

(Published by Dover Publications Inc., U.S.A. Price: Cloth $3.50. Paper $1.75)

To those who expect to find in this book a restatement or a new approach to Newtonian Mechanics let it be said at once that this translation of one of the last works of the celebrated nineteenth-century mathematician is indeed a new approach; but an entirely new approach to mechanics in its most general form. The principles laid down by Newton and Hamilton are discussed in a lengthy introduction, and discarded not because of admissibility or correctness but inappropriateness. The laws of mechanics are reduced to a single fundamental law with admirable simplicity. This has recourse to no elements other than space, mass, and time. Force, as it appears in Newton's laws, is derived from these elements.

It is not an easy book to read and will appeal more to the mathematician than the engineer. The general nature of the propositions and the rigorous formulation of the principles render its application by the normal mathematically equipped engineer unlikely. These very features will appeal, however, to the research worker in unfamiliar fields of physics where the laws of Newton do not seem to apply. J.P.F.-S.

AVIATION CARTOGRAPHY

(Published by Library of Congress, Washington. Price 85 cents.)

This is a useful pamphlet of some 114 pages, of which a third is given up to an historical account of the development of Aviation Charts since the beginning of the century.

The remaining two-thirds are devoted to a bibliography of books and charts arranged alphabetically by authors or organizations, and also by subjects, including headings by countries.

A very useful compilation for anyone requiring information on this subject. C.C.P.

THIRD REPORT FROM THE SELECT COMMITTEE ON ESTIMATES. SESSION 1955–56

(Published by H.M.S.O. Price 14s.)

The Select Committee was appointed by Parliament "to examine such of the estimates presented to the House as may seem fit to the Committee . . . and to report what, if any, economies consistent with the policy implied in those estimates may be effected".

The third report deals with Works and Buildings of the Service Departments (Army) and starts off with the actual report and recommendations of the Committee, which is covered in twenty-six pages.

After this follows, in some 300 pages, the verbatim questions and answers put to Senior "Q", Engineer and Finance representatives of the War Office and each Command in the U.K.

The Report itself is of special interest to all officers on Works Services as stating clearly some of the main points in Works Organization, and in the Control of Expenditure.

The verbatim questions and answers are also well worth careful study, at least by the more senior officers dealing with works services, as they show what such officers ought to know and be prepared to answer when called upon. There are also a number of interesting appendices, containing special reports submitted by the War Office and Commands.

Taken all round this is a really interesting official document, and once you begin reading it you will want to continue. C.C.P.

INFINITE SEQUENCES AND SERIES

By Konrad Knopp

(Published by Dover Publications Inc., New York. Price $1.75)

This book will be of interest to those readers who believe in mathematics as an end in itself; but if like the majority of engineers they consider mathematics as a powerful tool to aid them in the solution of the various problems confronting them, then this book may exasperate them.

One imagines that when a book is written covering old and familiar ground that the author has new light to shed or considers that his exposition is clearer than the original works on the subject, or those that have preceded it. Unfortunately, in this case it is not so.

The work is a translation and as a consequence deals with the work in a somewhat heavy and formal style. Most engineers will concede the importance of the subject, and the need to establish whether any particular series they have called to their aid is convergent or not; but because of this importance they will use tests of convergency set out more succinctly and in more familiar terms than those listed in Chapter III.

It is difficult to indicate a class of reader to whom this book will appeal. J.P.F-S.

ASYMPTOTIC EXPANSIONS

By Professor A. Erdelyi

(Published by Dover Publications Inc., New York. Price $1.35)

As stated in the foreword, this book was based on a series of lecture notes given in the California Institute of Technology, prepared under contract for the American Office of Naval Research. It admits that the work lacks finish. This impression is borne out as the reader progresses through the one hundred pages comprising the book. Symbols and terms which are by no means common on this side of the Atlantic are introduced without previous explanation. In the section of the book dealing with the method of steepest descent, the reader is conscious of a lack of explanatory notes which presumably accompanied the original lectures at the time of their exposition. Many of the references which presumably shed light on obscure points are unlikely to be found in most reference libraries, a point which considerably detracts from the value of the book. The above shortcomings make the book difficult to read and only likely to be of use to the specialist who may have attended the original course of lectures. J.P.F-S.

CALCULUS, REFRESHER FOR TECHNICAL MEN
TRIGONOMETRY, REFRESHER FOR TECHNICAL MEN

Both by A. A. Klaf

(Published by Dover Publications, New York. Price: $1.95 each)

These two books are each made up of a large number of questions with their solutions, on a mathematical basis, together with a few practical applications to engineering.

They should be of considerable use to anyone wishing to brush up their calculus or trigonometry. C.C.P.

Technical Notes

ENGINEERING JOURNAL OF CANADA

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

The St. Lawrence Seaway and Power Project

The whole technical section of the September issue is devoted to a series of papers describing important aspects of what will be the longest inland waterway ever created for ocean-going ships, connecting the Great Lakes to the mouth of the St. Lawrence River and the Atlantic, 744 miles away. Chicago, on Lake Michigan, and Duluth, Port Arthur, and Fort William, on Lake Superior, will become "ocean" ports, though the sailing distance to the Atlantic will be well over 2,000 miles in each case.

Canadian enterprise has previously created 14-ft. channels to enable small vessels to get into the lakes, and the Welland Canal, between Lake Erie and Lake Ontario, was opened in 1932. The Welland Canal, built in anticipation of the extension of deep-draught navigation, sets the standards for the new seaway. The controlling channel depth is 27 ft., the bottom width 200 to 450 ft. according to bank conditions, and the locks 859 ft. long and 80 ft. wide, with a minimum depth of 30 ft. over lock sills. These locks will lift ships a total of 580 ft. to Lake Michigan, and some 600 ft. to Lake Superior.

Following a historical review, compiled primarily with reference to the work of members of the Engineering Institute of Canada, are three interesting papers covering respectively general design, mechanical design features, and the use of hydraulic models in planning. Points brought out in subsequent discussions, printed in a separate section of the publication, are unusually interesting and informative.

Notes from *The Engineering Journal of Canada*, October, 1956.

Growth and Development of Large Electric Power Systems

This review of the development of electric power in Canada is written, not for the specialist, but for the interest of engineers in general. It describes the progress made in the last fifty years, summarizes present practice, and suggests the probable trend of future expansion. Hydro-electric generation is already used extensively, and few undeveloped sites of adequate potential output remain; the gas turbine is likely to be adopted on an increasing scale in the Western Provinces; and nuclear power seems likely to supplement, and eventually to replace, steam plant using conventional fuels, from 1965 onwards. Total production in 1955 amounted to about 80 billion kWh. and is expected to increase to over 100 billion kWh. by 1960.

Lateral Rigidity of Steel Building Frames

Hitherto the question of the rigidity required in buildings has usually been dealt with by mainly empirical methods. In modern construction, masonry walls have given place to lighter and more brittle cladding materials, more exact design tends to lighten the basic structure, and window area may be almost continuous. The modern building frame thus carries a higher proportion of wind loads and, being itself of lighter section, may suffer extensive lateral deformation, and increased strain at connexions. This paper describes an analysis of single-storey structures with twenty-seven different bay-span-height combinations, on the basis of probable movements related to building materials, and tabulates the results calculated for both rigid and semi-rigid frames. The most interesting conclusions drawn are:—

(*a*) That since the elastic design method results, in general, in columns that are too flexible, a plastic analysis has little practical application for the type of frame examined.

(*b*) That in most cases lateral movement should be a design criterion.

Application of Welded Design to Hydraulic Turbine and Valve Manufacture

This paper is of general interest because it exemplifies convincingly the substantial advances made in the technique of welding steel plate electrically, and the advantages of adopting fabricated construction in preference to iron and steel castings. An excellent series of photographs illustrates the size and complexity of components manufactured by this means. Fabricated design is not hampered by considerations affecting the quality of castings, and the use of special alloys and of stainless clad steel is relatively simple.

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

Canadian High-Voltage Overhead Transmission Lines

The rising cost of materials and labour, coupled with the rapid expansion of Canadian power distribution, has encouraged modifications in design and construction. No radical changes are proposed, but investigation shows that some re-appraisal of design assumptions is permissible. For example, there is substantial evidence that maximum wind loads do not coincide with maximum ice loads. This paper illustrates the advantages of a practical approach to design problems.

Hamilton River Survey, Labrador

This is a most interesting account of reconnaissance and survey work, carried out in mainly unexplored territory, to record essential data for a major hydro-electric development project. The preliminary ground reconnaissance was done in sub-zero weather, using Beaver aircraft for daily trips from base camp, and the information acquired in less than three weeks made it possible to determine the extent of full survey required, and to plan the summer work in detail. The system of "barometric levelling" used is particularly interesting.

Later work included the establishment of ground control for air survey, and a comparatively small area of ground topo survey; underwater soundings, both by lead-and-line, and by echo sounder; appraisal of annual precipitation and run-off, and the establishment of stream-flow gauging stations; geological and soil survey, including geophysical exploration by seismic sounding; and air and ground reconnaissance of a 100-mile access route and of the proposed electricity transmission route.

The results achieved in the available time, and in the conditions prevailing in Labrador, were largely due to the use of modern appliances and techniques, and in particular to air survey, seismic sounding, and the skilful employment of versatile fixed and rotating wing aircraft. The modern Sapper officer will find plenty to think about in this paper.

Project Vanguard—Earth Satellite

The earth satellite to be launched by the U.S.A. during the international geophysical year is likely to be a sphere, about 20 in. in diameter, and weighing about 21½ lb. It will contain scientific instruments, a tracking transmitter, and a power supply.

To launch it into its proposed orbit three-stage rocket propulsion is to be used. The first two stages will be finless rockets, with gimbal mounted power plants, the first using liquid oxygen and a mixture of ethyl alcohol, gasoline, and silicone oil, forced into the thrust chamber by steam turbine pumps, the second using nitric acid and dimethylhydrazine fed to the thrust chamber by helium pressure. The third stage will be powered by solid propellant, and it will also include a device for imparting spin to the airframe.

The launch is to be vertical, but a gradual tilt eastwards will bring the device towards horizontal at a height of 30 to 40 miles, and a speed of between 3,000 and 4,000 m.p.h. When exhausted, the first stage will fall clear, and the second stage will take over, burning out at about 130 miles up, having attained a speed of some 11,000 m.p.h. The assembly is then expected to coast into the satellite trajectory and, at a height of about 300 miles, the second stage will fall free, and the third stage ignite and accelerate to about 18,000 m.p.h.

The orbit should be elliptical, with perigree about 200 miles from the earth and apogee some 800 miles out, one revolution being completed in approximately ninety minutes. The lifetime of the satellite depends upon the unknown composition of the upper atmosphere. It may be several days, weeks, or even months.

THE MILITARY ENGINEER

Journal of the Society of American Military Engineers

September–October, 1956

Military Engineering for Modern Warfare by Major General Charles G. Holle, Acting Chief of Engineers.

In an authoritative article the author calls attention to the fact that while in modern warfare new developments in weapons and techniques follow each other in rapid succession and their effects on strategy and tactics are widely discussed there is relatively little publicity on the military engineering problems such developments present. He considers it of great importance that these changes in military engineering problems be more widely understood.

While he remains confident that military engineers have the ability to deal successfully with these foreseeable problems of the future it must not be ignored that they are relatively, today, not so well prepared for them as in 1941.

Nuclear development, jet propulsion, electronic controls and the possibility of space platforms have had revolutionary effects and on the engineering side considerable attention is being given to (1) the necessity of being able to build, manoeuvre and fight, on land, air and sea, in any part of the world, including the frigid zones, (2) the requirement for ground operations in dispersed formations to minimize the target presented to the enemy, and (3) the achievement of increased mobility, to enable ground forces to concentrate quickly for decisive action and then disperse with the utmost speed for safety.

Having annunciated these important factors affecting engineer problems of the future the author deals in detail with work being done by the "Snow, Ice and Permafrost Research Establishment", the "Arctic Construction and Frost Effects Laboratory" and the "1st Engineer Arctic Task Force" which makes summer expeditions to the Greenland Ice Cap. He then considers engineer problems in hot desert climates, and in airfield design and construction in both rigid and flexible paving materials to keep pace with modern aircraft requirements including the B-52, B-47, and J.A.T.O. and R.A.T.O. units, producing surface temperatures on concrete of 2,000° to 3,000°, due to jet blast.

Under "Effects of New Weapons and Combat Methods", the problems of launching facilities for medium and long range missiles are considered together with those of protective construction against atomic blast.

Combat engineering, with its requirements of increased mobility, presents a long list of problems, including the development of a complete range of airborne equipment. The Corps of Engineers, with major co-operation from industry, has some 400 major items of equipment under development in the current programme of the Engineer Research and Development Laboratories at Fort Belvoir. Possibly the most interesting of these is the pilot model of an atomic plant for the production of electrical energy and heat at remote stations. This plant is due to operate in 1957 and all component parts will be transportable by air. A single plane trip should provide fuel for twelve to eighteen months operation.

From this condensed four-page article and six interesting illustrations summarizing the problems on which the Corps of Engineers is working, the author hopes that the size and complexity of the military engineering requirements of the future may be visualized and not under-estimated.

CIVIL ENGINEERING

Notes from *Civil Engineering*, August, 1956.

Hurricane Damage to Road Bridges in Grenada

The article describes the aftermath of a hurricane experienced in the Island of Grenada, the largest of the Windward Islands. Though only 21 miles long by 12 miles wide it is covered with some 500 miles of road. The interest in the article stems from the factual description of how eight bridges varying from steel plate girders to R.C. beams and slabs suffered from the combined effect of floods and high winds, and it gives some indication of what the effect of blast and tidal waves associated with a nuclear explosion might accomplish against this class of structure. A surprising feature is the amount of lateral thrust bridges were able to withstand without being displaced bodily, the main cause of damage being scour behind the abutments when the main channel became blocked with debris. The article includes ten photographs of damaged bridges.

Composite Timber Concrete Construction

The article by Mr. R. G. Pearson describes a novel method of reinforcing concrete with timber. Essentially the construction is reinforced concrete, but instead of internal steel rods, the reinforcement is timber on the underside of the concrete. This feature enables the characteristics of the two materials to be fully developed. Concrete provides a smooth hard-wearing surface; while the timber is relatively light in weight, easy to fabricate, and form work is either eliminated or becomes very simple.

Numerous composite timber-concrete structures have been built in the U.S.A., where the usual type comprises timber sub-deck of preservative treated planks on edge, spiked together side by side. Alternate planks are set at different heights so that when the concrete is poured a key is formed with the timber. In addition steel plates $\frac{3}{32}$ in. thick are driven into slots cut into timber sub-deck at spacings calculated to meet the horizontal shear requirements. It is stated that the composite structure is in many cases more economical than the equivalent in reinforced concrete.

A Floating Purification Plant

The floating waterworks which has just gone into service in Iraq will be of interest to Royal Engineer officers concerned with the supply of pure drinking water in remote areas of the country where the only source of water may be the bacteria polluted waters of rivers and canals. The methods of purifying such waters are well known and consist of settlement encouraged by sulphate of alumina followed by filtration through sand filters and chlorination. Local physical difficulties such as flooding and annual rise and fall of the rivers through a vertical range of as much as 40 ft., combined with the incapacity of the soil to withstand heavy loading led the Government to consider a floating waterworks. Because it floats, it requires no foundations; and for the same reasons it is unaffected by changes in river level. It comprises a series of welded units bolted together to make a vessel, on top of which is mounted the pumping and treatment plant. The over-all dimensions of the unit are 38 ft. 8 in., 9 ft. 6½ in. and 12 ft. high. The maximum draft of the equipment is 6 ft. 11 in., and its total weight, including all ancillary equipment but exclusive of the filter bed is estimated at 14,200 lb. The plant is capable of treating water at an average rate of 1,200 gallons per hour against a head of 80 ft., with a maximum rate of 2,400 gallons per hour. The cycle of operations is completely automatic.

Prestressed Concrete for a Multi Span Bridge

The Mahi Bridge near Vasad in India is an extremely interesting example of how a series of prestressed concrete beams each 120 ft. long may be launched. To avoid the need for falsework because of the height above the river, the transportation and positioning of the prestressed beams was effected by the use of a pair of specially made launching gantries each 182 ft. long. These were cantilevered out to the far pier, and thereafter supported a pair of prestressed beams rolled out on tracks. A feature of the system is the launching of the concrete beams in pairs which enables the beams to be carried outboard of the launching gantries since they form a balanced system. This short article is well illustrated with three photographs and seven diagrams showing various stages in the launching of the girders.

Notes from *Civil Engineering*, September, 1956

THE VACUUM CONCRETE PROCESS

This process was first successfully applied to a contract recently completed in the borough of Godalming where the walls of four filter tanks were constructed by this method. The process required special form work so that the vacuum could be applied to the face of the concrete. Vibrators were used during the placing of the concrete, which had originally a water cement ratio of 0.45. The advantages of the system are that after the 30/35 minutes, the period that the vacuum is generally applied, the water cement ratio was reduced to 0.35 with a corresponding increase in strength, reduction in shrinkage and the possibility of recovering the shuttering after only 30 minutes. It was found on this contract that it was possible to complete the entire operation of erecting formwork, casting the concrete, and striking the formwork in four hours. Thus permitting two complete cycles in an eight hour working day.

Sixty uses of the formwork were carried out without damage, and the whole contract showed a saving of 75 per cent in time. Each 6 in. thick wall section was 19 ft. 6 in. long and 6 ft. 9 in. high. The labour consisted of a formwork gang of twenty-five skilled and two unskilled men. The article concludes that the results warranted the initial cost.

Notes from *Civil Engineering*, October, 1956

SOME ASPECTS OF SOIL STABILIZATION

The author introduces his article with a discussion on the vital question of cost and limits this to a comparison between a stabilized soil road base and granular material giving the same C.B.R.

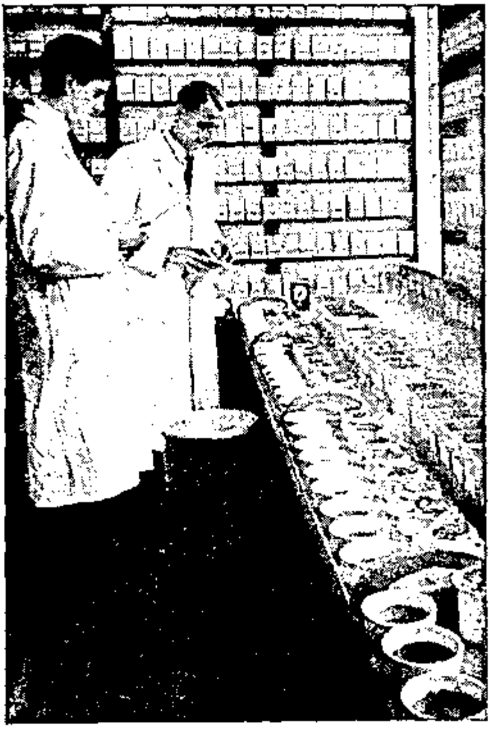
Examination has shown that soil stabilized bases will be cheaper than stone in areas further than ten miles from quarries. Savings affected by reducing the cement content by half vary from 10 to 20 per cent of the cost of stabilized soil; while the provision of a cheaper granular material than crushed stone generally entailed savings of up to 50 per cent.

The article continues with a review of the three main types of equipment in current use: mix-in place equipment, travelling mixers, stationary mixers. The description of the Barber Green travelling plant is of particular interest as it combines the mix-in place system with the plant mix system. An interesting application of soil stabilization described is its application to foundation construction of ordinary dwelling houses. It was ascertained that a saving of 22 per cent of the cost of providing normal foundations was achieved by using a stabilized soil raft foundation, where the soil was suitable. The foundations were subsequently loaded with 1½ times the design load under flooded site conditions and showed no sign of failures. The author concludes by discussing the effect on soil of a new chemical, calcium acrylate, a substance which is not available in large quantities at the moment; but should it become available it would be possible to produce stabilized soils with very high mechanical strength.

THE SAFE USE OF CARTRIDGE HAMMERS

The avoidance of accidents with cartridge hammers was discussed by the London Building and Engineering Contracting Accident Prevention Group. The article lists some fifteen points which contributed to accidents with this type of equipment. They may be summarized by saying that the instructions attached to the box encasing the tool if followed will prevent the majority of accidents. It stresses the need to use a washer to prevent the bolt being shot through the materials, and the need to observe the safety precaution of keeping the gun held against the wall for at least thirty seconds after a misfire and placing the cartridge in water when removed.

from Tea



to Tobacco

A cigarette and a cup of tea—two of the minor pleasures of life, but such as few would be without. This is as true of the members of Her Majesty's Forces as of most of us.

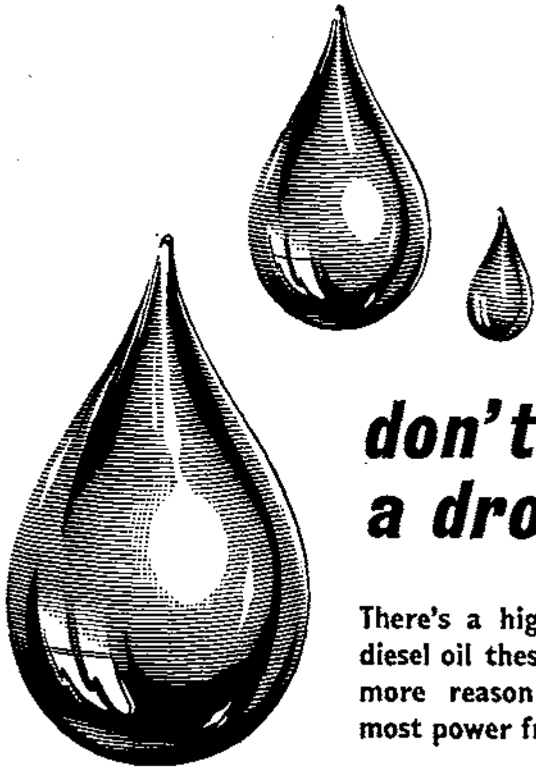
As the official caterers to Her Majesty's Forces, Naafi has the task of ensuring that a cup of tea and a cigarette are always readily available.

So it is that Naafi serves more than 154,000,000 cups of tea a year and is one of the biggest buyers of tobacco in the United Kingdom. behind the scenes, the vast network of Naafi's buying, testing, sampling and distributing organisations deliver blended teas and tobaccos and cartons of cigarettes wherever Servicemen and their families may be.

To see that Servicemen and women enjoy to the full their tea and tobacco is but one of the many and varied duties of....

...this many sided NAAFI

The official canteen organisation for H. M. Forces, Imperial Court, Kennington, London, S.E.11.



For printing

serious and gay

MACKAYS OF CHATHAM

phone 2243-4

or write: Fair Row, Chatham

ROCHESTER BRANCH

137 High Street, Rochester Chatham 2551

Ford

★ ★ ★ ★ ★

FIVE STAR MOTORING

To people going overseas who are considering buying a new car:

To officers proceeding abroad, serving overseas or returning to this country for leave:—

We can offer any of the Ford range of cars **Free of Purchase Tax**, subject to currency and import restrictions in certain territories. These cars may be used in the United Kingdom for six months prior to exportation. We shall be pleased to send full details on request.

BROOK GARAGE

(CHATHAM) LTD. *Phone 3201/2*

315 HIGH STREET, CHATHAM, KENT

MAIN FORD DISTRIBUTORS

POPULAR : ANGLIA : PREFECT : CONSUL : ZEPHYR : ZODIAC