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Editorial

THE FAILURE OF THE TETON DAM, IDAHO—5 JUNE 1976

In simple terms embankment dams fall into three main categories:—

(1) *Earth*, with mass or reinforced concrete core wall to provide watertightness.

(2) *Rockfill*, constructed of large rock and made watertight with a concrete upstream face.

(3) *Zone filled*, combination of rocks and earths in zones relying on impervious soils for watertightness.

The Teton Dam was of the third type utilizing five combinations of materials, including a core of compacted clay, silt, sand, gravel and cobbles. It was some 95 m high, 1,000 m long and contained 8 M.m^3 of fill. Under the dam there was a 20 m deep key trench and a grout curtain of three rows of grout holes up to 90 m deep. The geology of the area is complex but in general it would seem that the base rock was volcanic rhyolite overlaid with alluvial sand and gravel overflowed by recent (geologically) volcanic basalt. The dam was designed by the US Bureau of Reclamation who are acknowledged to be among the leaders in embankment dam design; the design was a well tried one and was conservative in concept. The dam was the first major failure by the Bureau in their history of hundreds of dams. Under the US Dam Safety Act of 1972 the Teton Dam was one of several hundred excluded from the Act because the Bureau has its own safety regulations and programme of inspections considered to be second to none.

HOW could such a dam fail?

In general embankment dams fail through overturning, sliding, bursting or as the direct result of seepage. Prevention and control of seepage are always at the front of the designers mind as the carrying away of solids from the dam or its foundation, thus progressively weakening the dam, is a major area in design where risks cannot be calculated with any precision.

It would appear that the Teton Dam failed because of seepage but until the investigations are completed (there is talk of three separate investigations by the State of Idaho, by a Committee of the House of Representatives in Washington and by the Bureau itself), the engineering reason or reasons for the failure must remain speculative. The Press have referred to pre-construction controversy and to a lawsuit in 1973 to prevent its construction, the lawsuit was primarily instigated by environmentalists who were concerned with possible damage to deer and fish, though some geological evidence was presented apparently as "makeweight". In fairness, the Press have not been too reliable in their reports on the disaster, one well known newspaper even sited the dam on the wrong river!

As this is being written the theory generally in favour is that water eroded the fill by passing either round or under the grout curtain, through a hole in the grout curtain or through the walls of the natural canyon in which the dam was sited. An alternative suggestion is that an earthquake in 1975 (its epicentre was some 240 km to the south), may have damaged the dam or its grout curtain in some way, thus permitting seepage as the water rose behind the dam.

It is hoped that the investigations will also answer *WHY* the dam failed. *WHY* is not necessarily the same as *HOW*. Did financial, political or economic considerations encourage unjustifiable engineer risks? Was site selection over-influenced by non-engineering considerations? Was there a degree of over-confidence in the design and construction phases based on the almost unrivalled experience of the Bureau? We will have to wait and see.

Whilst not for a moment suggesting that over-confidence was in any way instrumental in causing the dam to fail, the disaster should be a reminder to all engineers, and particularly military engineers, of their responsibilities.

Many Members will recall accidents in military engineering which were the result of over-confidence. Accidents with high explosives, mines and grenades; equipment bridges coming off rollers or failing to reach the far bank; crane slings slipping and a host of others; many the result of over-confidence and "chancing-it". Errors in engineer judgment are always unfortunate but errors due to over-confidence, often the end-product of over familiarity, are criminal.

Engineering responsibility is a very real thing and cannot be abrogated. Of course engineer risks must be taken, they are taken daily, but they must not be taken lightly. There are degrees of risk, there is a time and place for risks, but all risks must be based on sound judgement and experience and not on over-confidence and familiarity.

Centenary Meeting of the Institution of Royal Engineers

ARTICLES AND CORRESPONDENCE INSPIRED BY THE MEETING

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CENTENARY MEETING—FUTURE OF THE CORPS

Sir,—In his contribution to the discussion Colonel Townsend-Rose commented on the lack of professional experience in the Officers of the Corps. This is particularly true in the E and M field and even more especially at technician and tradesmen levels.

Whilst in Technical Training Group at RSME, I was very concerned at the low level of practical experience of the students on electrical and mechanical upgrading courses. In many instances the only practical work they had experienced at their trades had been on their previous course at RSME. Accepting that we do need trained tradesmen in the Corps this is a serious shortcoming affecting our ability to perform our designated tasks. It also has a disadvantageous effect on recruiting.

If we are to maintain an E and M presence we must provide electrical and mechanical work for our tradesmen, technicians and of course PQE Officers (each of these three levels must be interdependent). The normal Overseas UK Projects may provide the necessary B & CE experience but they do not normally provide any worthwhile E and M work. Before we lost Works Services this situation did not arise, there was ample E and M work for all levels. The experienced people brought up in Works Services are fast disappearing; indeed in about two years time the only Members of the Corps who will gain similar experience will be the few who serve with PSA.

Certain categories of major emergencies could require considerable E and M experience, for example the power workers strike in Northern Ireland. Prior to 1958 the RE Works Service would have coped with this in its stride. Attempts to solve this type of problem by training and courses etc will never be effective, it needs experience based on permanent E and M commitments.

What are the possibilities of acquiring such commitments?

In Germany there are four major RAF Stations, at Wildenrath, Laarbruck, Bruggen and Gutersloh. If the works side of these stations could become our responsibility this would provide all the experience we would need. Each airfield could come under a peace-time DCRE with a complete works service structure down to tradesmen level. If this is considered to be over ambitious there is the possibility of complete Works Services responsibility for one of our own barrack areas, say RSME. Although mainly maintenance work it would at least provide some experiences particularly on the electrical side.

It is suggested that unless this lack of practice in electrical and mechanical work is corrected, from tradesmen, thro' technicians, thro' E and MO and up to PQE, then the E and M capability of the Corps will be placed at risk.—Yours faithfully, A S Jenkin.

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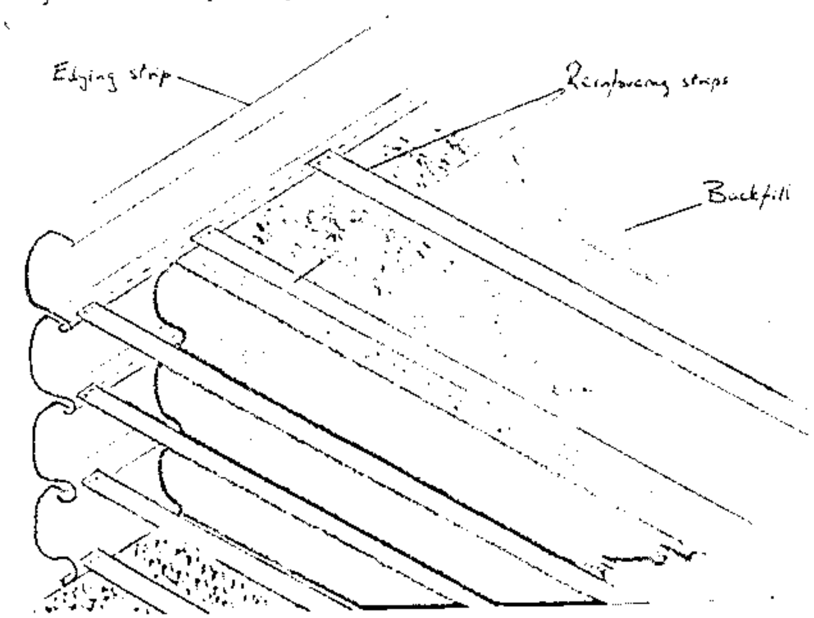
CENTENARY MEETING—INNOVATION

Sir,—Professor Alan Harris, speaking at the Centenary Meeting of the Institution of Royal Engineers, made a point of the Corps' historical record of innovation in many fields and suggested some specific subjects to which we should now be looking. One of these subjects was Reinforced Earth, and your Editorial asking for written contributions gives me my cue to perhaps give a lead in this direction.

The principle of Reinforced Earth is very simple and involves harnessing the internal friction of soils to create a coherent material in which the individual grains behave as if they were integrated. It can be used in any earth fill conditions and is achieved by laying strips of reinforcement on each layer after compaction. The self weight of fill automatically creates the bond necessary between earth and reinforcement, and the structure is contained by connecting the strips at their outer edge to relatively thin skin elements. The sketch illustrating the system patented by M Henri Vidal, the innovator of Reinforced Earth, may make this clearer.

The special advantage to military engineers is the exceptional lightness and portability of all the component parts, which replace the massive logistic problems in-



herent in the alternative reinforced concrete structure. If the sub-base is strong enough a reinforced earth wall/embankment can be built to any height, since the stress in the lower elements is not increased by additional surcharge. Having mastered the principles of Reinforced Earth it is easy to envisage the possibilities of using it with most "indigenous" materials—hessian, bamboo, sheet metal from drums, CGI etc, so we have the possibility of using both purpose built, light, permanent materials developed for military use, or any local material which may be to hand.

It is pleasing to report that the Corps has not in fact been overlooking this subject, and Major-General Tickell, when he was E-in-C, gave personal encouragement to me to pursue the matter under his sponsorship. Unfortunately, due to the consideration of the three-year time bar after a year's study, I was not able to take up the offer. However if the Corps can spare an officer for a year we would not only help to sustain our standing in the Civil Engineering field but probably find a neat solution to some of our Field Engineering problems. Have we any volunteers?—Yours faithfully, C Spottiswoode.

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CENTENARY MEETING—CLOSER TIES

Sir,—History, as General Jackson reminded us, can inspire but it cannot be used to forecast the future. It is, as he said, no more than the data bank of our inherited experience. For the policy maker, facts drawn from this almost unlimited store must be highly selective or they will swamp. What sort of information should be "retrieved"?

Today it is not change, but the rate of change, which makes things so difficult. While eschewing trendiness, the important point is to recognize trends. To decide what should be planned for and what resisted.

Case histories can well be studied. Liddel Hart's account of the resistance, both within and without the War Office, to mechanization in the thirties, springs to mind. After reading it one can only ask "are we sure that in some unrecognized way we are not also being guilty (according to Liddel Hart, hideously guilty) of similar inability to recognize when traditional ways must be flung overboard". Stimulation to self questioning is a great thing!

One present trend in the Civilian Engineering world is of interest. The various Civilian Institutions are much worried about how they should represent themselves as one Engineering Profession and how they can work more closely together. To an outsider, it could seem odd that within the Services the Engineering Corps are seemingly not interested whether their own relationships are close or not. For instance, will not the trend to pin-point accuracy, leading possibly to deployment by individual weapons rather than, for example, by batteries, not demand much closer co-operation not least by the Technical Arms? Should at least the three Institutions, R Sigs, REME and our own not gain by knowing each other better? It seems a pity that representatives of our sister Institutions were not invited to our Centenary Meeting. Perhaps they were and did not come!

Major Hobden has suggested, in this correspondence, that there should be greater opportunity for a given appointment to be open to both Civilian and Military applicants. History tells us that in the Corps' heyday (the second half of the nineteenth century say) RE Officers took on many jobs and activities which would now be considered the province of the civilian. How can we perhaps create again the opportunities which led to twenty or so RE Officers being FRS? Will we ever again supply the President of one of the Engineer Institutions (see Lieut-Colonel Tusan's article on "Some Sapper Presidents" in the September 1975 *Journal*). If we want closer ties between the Civil and Military Engineering professions, why not start by creating closer ties between ourselves!—Yours faithfully, M L Crosthwait.

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CENTENARY MEETING—FUTUROLOGY

Sir,—When I attended the Centenary Meeting of the Institution of Royal Engineers I must confess to having been rather disappointed; possibly I was expecting something rather more exciting in the nature of a "brain-storming" session, but we did not enter the realm of futurology, and such advanced methods as Delphi techniques were not even mentioned in lieu of the crystal ball! However, on reading the excellent account in the *RE Journal* I was able to obtain a more hopeful view of the value of the evening. In particular I was impressed by the great importance of the attention given to the need for ever closer association between military and civilian engineers.

The suggestion of interchangeability made by Major Steve Hobden strikes a chord in my own experience. For such contribution as Sapper officers have had the privilege of making in the field of military bridging, new techniques and equipment design was only possible because of the closest team-work between the military and civilian engineers at the Experimental Bridging Establishment (later MEXE, now MVEE Christchurch). Even today the design teams are fully integrated; long may this association and interchangeability continue!

Returning to futurology, however, I suggest that a more systematic approach be made to assessing new technology much of which may not be fully effective for twenty years or more in its impact on military practice and equipment design. Just as we need to train now the decision makers and practical engineers of the future, so we need some now to become conversant with the technologies which will be commonplace many years ahead. Spotting winners is not just a matter of chance, but requires knowledge and painstaking study of form! So perhaps the debate could be widened to include methods of encouraging the innovators of the future, bearing in mind that both inventive visionaries such as G le Q Martel, and far-seeing engineering administrators such as A E Davidson will be required.—Yours faithfully, H A T Jarrett-Kerr.

FOOTNOTE ON FUTUROLOGY:—
Futurology is the science of forecasting the future, both in the technological field and in social developments, that will govern the requirements from technology.

Various methods and techniques are a help, for example:—

Brain-storming "A group of people, not necessarily all from the marketing department, get together to answer a question such as 'In how many ways can we improve our product (or our service etc)?' If suggestions, however wild, are vigorously encouraged and all criticism of them is banned—this is vital—a large number of ideas, some of them entirely new, are created" (ref, *Corporate Planning—A Practical Guide*, John Argenti—G Allen & Unwin Ltd 1968 Ed, p 246).

Delphi techniques were developed at the RAND Corporation as a means of making systematic the attempts to bring the intuition and knowledge of a group of qualified individuals to bear upon the future possibilities in a given subject area; forecasting future technologies is such an area. The method involves three or more rounds of questions to a panel of experts (ref, eg "Technological Forecasting—A Criticism of the Delphi Technique" by R E Overbury in the *Journal of the Society for Long Range Planning*, Vol 1, No 4, June 1969).

* * *

1976 Corps Annual General Meeting

ADDRESS BY ENGINEER-IN-CHIEF

At the Annual General Meeting of the Corps, held on 23 June 1976, the Engineer-in-Chief, Major-General J H Foster, spoke on the state of the Corps.
He said:

The last year has again been a busy one for the Corps. When I spoke last June it was shortly after the Defence Review and I explained in broad outline the effects this would have on the Corps. In addition to the usual wide variety of tasks, staffs and units have been busy carrying out a series of studies and trials on the more detailed aspects of the reorganization. We work against a very tight set of limitations, particularly in manpower, which leave little room for anything other than the absolute essentials. Gone are the days when the militarily desirable could be found a place in our organizations.

DEFENCE REVIEW

As I have started on the Defence Review, I will deal with this subject first. In BAOR there are extensive changes resulting from the restructuring, 1st British Corps will in future have four Armoured Divisions of a new style, without any Brigade Headquarters. The Divisional Engineers will be reorganized into one large regiment of three field squadrons and a field support squadron. This saves overheads compared with the present smaller Brigade Engineer Regiments and, being a larger regiment, should provide more flexibility and a more satisfying command. The first of these new regiments—2nd Armoured Division Engineer Regiment—forms up at Osnabruck in September this year. Although it may seem to be "all change" yet again in the divisional engineers, it is important to remember that at squadron level life will look much the same, as all the present field squadrons in Germany remain in this role although some will have to change location. In addition, we have already converted 73 Amphibious Engineer Squadron to a field squadron. We are having to make some adjustment to the armoured engineer and field support squadrons but throughout the Corps I am determined to preserve our historic squadron numbers. In this respect two squadron numbers will be transferred to the Junior Leaders Regiment.

We have been looking carefully at the Armoured Engineers. The Centurian AVRE will be going after some seventeen years service, once the new Combat Engineer Tractor comes into use. This is a good new equipment that has done well on its trials. It will mostly come into service in the new Support Troops of the Field Squadrons, although some will be integrated with the Chieftain Bridgelayer. Our first thoughts for the bridgelayers were to put a troop of them in each Armoured Division Engineer Regiment. Trials have shown, however, that there are merits in concentrating them into a Corps Armoured Engineer Squadron in peace and we are having a closer look at this.

The trials also highlighted the problem of command and control of engineers within the Division. The load on the Regimental Commander, providing both engineer advice to the Divisional Commander, and commanding a big regiment as well as all other Regular and TAVR units in the Divisional area, would be too much for one man. A case has therefore been made to retain a CRE at each new Divisional Headquarters.

In UKLF the general outline of restructuring that I gave last year remains the same. Restructuring has begun, but the majority of our units will reorganize next year. It is interesting to note that the Army has re-introduced the term "Field Force". We have decided to call the squadrons from the present airfield regiment Field Squadrons (Construction), and we are now tackling the problem of how we maintain their expertise in their specialist roles. In UK our regular regiments will retain their present numbers and locations. The T & AVR is in even more demand than before and we are still working out the best grouping for units in our TAVR Brigades, but we hope that we can meet our new commitments with a minimum of rearrangement.

One of our problems concerns the future of both 9 Independent Parachute Squadron and 131 Independent Parachute Squadron TAVR, with the reduction in the Army's parachute capability. 9 Squadron is now only required to provide at any one time one composite troop in the parachute role. With reserves, however, this represents a sizeable portion of the squadron. We have had considerable discussion within the Ministry of Defence as to the future title and dress of 9 Squadron. I am very glad to be able to announce that the Army Board have decided that in view of 9 Squadron's particular history and traditions and the extent of its continuing commitment in the parachute role, it should continue to be entitled 9 Parachute Squadron and all ranks on its establishment may continue to wear the maroon beret, as they have done since its first formation in 1941. I should like to take this chance to say how grateful I am to the Army Board for their careful consideration of our case and to all those both in and out of the Corps who have helped us get it through. I am sorry to say that 131 Independent Parachute Squadron will lose its parachute role, but already part of the squadron is required to support the Royal Marine Commandos and I hope that all members of the squadron will be able to wear the green beret, so that there will be a happy outcome.

On the Works Side, we are rearranging our organizations. We are revising the Military Engineering Services (Field) establishments, both Regular and TAVR, in order to produce the best organization for peace, and which will fit into the Engineer Works Organization in BAOR, of which it is a large part in war. Initially they will be grouped into a Military Works Force, located at Barton Stacey, and will move to the RAF Station at Hullavington when this is handed over to the Army.

A major slice of our cuts is falling on the Engineer Support organization, although in the end I do not consider it is faring too badly. We are making savings by moving most of the staff of Headquarters Engineer Support Group to Long Marston, where they will be amalgamated with the staff of Central Engineer Park. We are also looking at ways in which we can bring the Military Works Force into a closer relationship with the Engineer Support Organization, because I feel that it will give a more integrated grouping of professional engineering support to Corps activities world wide. The other part of the Defence Review proposal for the UK Support Organization concerns our Engineer Parks. Economy measures are going to be made by co-locating these with Ordnance units where possible, and these moves will be coupled with reviews and reductions of stocks. Although the latter may mean some loss of flexibility and response to the unexpected, the general effect on the user should not be too noticeable.

I have, so far, concentrated on describing the effects of the Defence Review on our organizations in Germany and the UK, and I will now do a quick review of our plans for the future elsewhere in the world, at the same time describing the events of the last year in these places.

Starting in the Far East, the effect of the Defence Review in Hong Kong has resulted in the closure of HQ RE and the withdrawal in cadre form of 54 (Hong Kong) Support Squadron to become the third squadron of the Junior Leaders Regiment. The Commandant, the Gurkha Engineers, does however retain his other hat as Commander Royal Engineers, and some of the plant and stores of 54 Squadron have been absorbed into the newly formed Headquarters Squadron of the Gurkha Engineers. We have retained the two Gurkha Engineer Squadrons, and thus we should be able to provide adequate engineer support in the Colony although it will be less easy to provide the necessary back-up support for visiting squadrons. Meanwhile our sappers in the Far East have been busy, with several projects in Hong Kong in support of both the military and the civil communities. The major project was the construction of a permanent camp of platoon size on the Island of Ping Chau, which is about twenty-five kilometres North East of Hong Kong and only one kilometre from the Chinese coast. Everything for this project, including all the services, had to be constructed from scratch. The Gurkha Engineers have also had the opportunity of undertaking exercises in Brunei, (where two old oil rigs belonging to Shell were successfully demolished), in the New Hebrides, the Philippines and in Australia.

In Cyprus, HQ RE has also been disbanded, and 62 Cyprus Support Squadron has been reorganized, its military strength having been halved. We still hope to be able to run training exercises in Cyprus in the future and are currently constructing a Roll-On/Roll-Off jetty at Akrotiri for use by LSLs. A squadron has just finished major improvements to the Akrotiri slipway. I mentioned last year that we had been asked by the United Nations to repair the craters on Nicosia Airport caused by the Turkish bombing, and this task was carried out very successfully providing us with excellent training and the island with two usable runways.

The contract for the Specialist Team in Malta runs out this year, but we are trying to get its life extended, and at the same time are looking at its long term employment possibly elsewhere. Meanwhile the team are extremely busy and had responsibility for expenditure during the last Financial year of over £1·2 m. Their most spectacular project is the design and planning of the complete Laboratory Wharf area as a container terminal, and for supervising its construction. They also have similar responsibility for two housing estates and several hospital services.

Finally in this run round, Gibraltar. 1st Fortress Squadron will be slightly reduced in size next year, and further reduced in 1978 to become a Specialist Team (E & M). However, our close associations with Gibraltar are continuing. Last July a squadron from UK undertook a three month exercise there doing work in support of the Property Services Agency, and during this time they renovated several quarters, installed twenty-one mobile homes to help relieve the quartering situation, and resurfaced four sports pitches. In addition to the very real financial savings involved, these tasks would not otherwise have been done for several years due to labour shortages in Gibraltar, and the exercise was so successful and such good training value that at the moment another squadron is there under-taking similar tasks.

Our surveyors have also been affected by the Defence Review, and 42 Survey Engineer Regiment in Barton Stacey will shortly reduce from three Squadrons to two, their reorganization starting this month and finishing by April 1978. In Germany, the amalgamation of 14 Field Survey Squadron and 3 BAOR Map Depot will also be completed by 1978. Surveyors have again been fully committed throughout the world, although the number of overseas field tasks have been limited for financial reasons. The work of the field surveyor is changing, from the original surveys typified by Borneo, Aden and more recent work in Kenya, to the many and varied tasks now required in support of the services in Europe. Another landmark in the history of the Corps is the start, at last, of the rebuild of the School of Military Survey at Hermitage, first agreed in the 1950s. Work started on this rebuild last month.

The Postal Branch of the Corps suffered less than most from the Defence Review, with the main effect being the amalgamation last February of all postal units in the 1 (BR) Corps area. This reorganization has created greater flexibility, and has already proved most successful. Postal support has been provided for exercises in over seventeen countries in the last year, and over £7·5 m changed hands over the counter in the Financial Year 1975/76. Those of you who have been to any of the major military displays recently will have seen the Postal Display Caravan, which has been showing the work of that part of the Corps and also very successfully selling the series of Corps "First Day Covers".

NORTHERN IRELAND

That is all I am able to say at the moment on the Defence Review, and I wish now to turn to Northern Ireland, where our involvement in the engineer role has remained undiminished over the last year. One field squadron is permanently stationed in the province, and we maintain two others, from either UK or Germany, on four month tours. In addition we have supporting units, Military Engineer Services, Surveyors and Postal and Courier operators. Our workload has if anything increased during the period and we have periodically had to send additional reinforcements, ranging from a troop to a squadron, to try to reduce the backlog of work. Our effort is concentrated on rebuilding sangars, cover from view screens and the whole range of defences in a more permanent and unobtrusive form, which will last longer and in the long run cost less. A lot of effort is still being put into improving the appearance of the defences. We are also trying to encourage the civil population to clear the wreckage and debris of the last few years in a cosmetic campaign. Our surveyors have been providing a wide variety of appropriate and up to date maps of the area. Some 400 different maps are now available from the map store in Lisburn.

In addition to our engineer tasks, we are also from time to time called upon to provide a Regiment in the infantry role, and a regiment from Germany, reinforced by an extra squadron has spent the last four months in Londonderry in this role.

Before I leave Northern Ireland, I would like to make particular mention of a relatively new subject—Search. We are responsible for the training of All Arms Search Teams and Search Advisers, and this training is done both at the RSME and in Germany. It has turned out to be a growth industry and we have gained and are still gaining a great deal of experience. Over the last two years, the terrorist has progressively developed his techniques of concealing and transporting arms, ammunition, explosives and other items such as uniforms and subversive literature. At the same time, he has improved his techniques of making booby traps and bombs, designed either to protect his hides or to cause casualties among the security forces. He is also developing the art of luring the security forces into killing zones—a practice that we call "The come-on". We have reacted by developing better and safer techniques, and by producing better search equipment. Our concept has also changed, in that we now employ not only specialist search teams but also routine infantry patrols on search tasks, and search is now a military skill to be learnt and practised by soldiers of all Arms. Some figures will show you the size of the problem. In 1975, a so-called "Cease-Fire" year, the security forces in Northern Ireland searched nearly five million vehicles, 26,000 unoccupied and 4,000 occupied houses, and we have more than 250 trained search teams (each of six men) in the Province at any one time. All these search teams, and each major unit has at least six, must be trained. In addition we train our own Royal Engineer Specialist Search Teams, who are primarily used for searches for Improved Explosives Devices; and we also train unit search advisers, who co-ordinate the operations of the search teams in their units, and ensure that a high standard of search skill is maintained by these teams. Thus you can see that the search training for Northern Ireland is a sizeable and continuing commitment for the Corps.

In the future, the terrorist's techniques will continue to evolve. He has the advantage in that he can set up a booby trap system and then sit back and watch how the security forces deal with the situation. This results in his next booby trap system being more difficult to deal with, as he improves his techniques and capitalizes on our mistakes. He is also able to buy highly technical devices, such as light sensitive switches, from the commercial market; in short he tends to hold the initiative, but we regain it with our new methods and our equipment and by acute awareness on the part of all the Security Forces.

EMPLOYMENT OF BAOR AND UK UNITS

Enough on Northern Ireland. Elsewhere there has been little sign of a reduction in the many calls made on the Corps, although the pattern is tending to change. We still walk a narrow path between the problems of too much separation and overstretch and keeping units busy with interesting and productive training. All this against a background of the reorganization and reductions in manpower. However, I am convinced that we are the better as a Corps for being busy and we have the rare advantage in peacetime training in that we leave the results of our labours for someone else's use and we have a sense of satisfaction in jobs well done.

We still visit countries abroad both on exercises and for projects and as an example of those in the last year, we sent a squadron to Kenya, where in a very successful exercise they constructed a fifteen kilometre road across a highly productive agricultural area in the foothills of the Aberdare Mountains. We are also increasingly requested to send small specialist teams to provide technical expertise and train the local labour force for similar projects, and this trend is likely to continue in the future. One such task occurred late last year, when we sent a well-drilling team to Botswana for three months, instructing the local geological survey department in how to operate the drilling rig Two other projects are in progress at the moment, one being a task to improve the harbour facilities at Bounty Bay on the Island of Pitcairn in the South Pacific, and the other designing, and supervising the first month's construction of a sixty kilometre road through very thick jungle in Peru. These latter tasks are undertaken on behalf of the Foreign and Commonwealth Office. We have also worked in the last year in Denmark, Norway, Sardinia, Sudan, Canada and Turkey, and our TAVR units have been equally busy in carrying out tasks in Germany, Gibraltar and Cyprus as well as in many parts, and some of the remoter parts, of this country.

Last year I spoke about the work we are undertaking on behalf of the Property Services Agency, in the execution of Works Services for the Army and the RAF. I said then that I expected our commitment to develop, and I am pleased to report that we are becoming more involved in work of this nature. Our commitment is of course nothing new, as we have always been required to work in areas where the PSA cannot carry out such tasks, either for security reasons, lack of time for contract action, lack of funds or lack of a contractor. The financial savings that can be made are considerable, and I have already mentioned the camp in Hong Kong and the two projects in Gibraltar that fall in this category. This year from July to September a squadron from UK will be undertaking a large part of the reconstruction of Reinsehlen Camp on Hohne ranges which will save over £200,000 on the estimated German contract cost. It will be the first project in Germany undertaken by a field force unit from UK, although units stationed in Germany have for some years done similar work, for example at Bracht, which have resulted in savings of many millions of DM.

We are also frequently being called upon to demonstrate equipment in support of Defence Sales, and the Medium Girder Bridge deserves special mention as it has become the best selling major item of engineer equipment since the Bailey Bridge; having been sold to eighteen countries. At the Royal Engineers demonstration last year, which was attended by over 2,000 visitors, twenty-seven foreign countries were represented. The RE demonstration was followed the next day by a very successful sales demonstration of the Combat Engineer Tractor, which has excited definite interest in several parts of the world. I have been asked to pass on the appreciation of the Defence Sales Organisation for the whole-hearted support they receive from the Corps. These and other demonstrations all take time and effort. Today there is a major Defence Sales demonstration at Aldershot, of all kinds of military equipment and this, to take an example, has taken a complete field squadron as well as effort from both Training Regiments. I believe that this is a very important part of our military life these days and our ability to sell equipment pays considerable dividends towards the future equipping of the Corps.

MANNING AND OFFICER RECRUITING

A year ago I mentioned that recruiting was improving and that we were getting almost more junior soldiers than we had places for. Junior recruiting continues to be good and we take every boy that we can fit in anywhere. Our adult recruiting has been much better and the combination of the two will go a long way to solving our recent undermanning problems.

Officer recruiting is showing signs of picking up but we still have a long way to go in getting quality as well as numbers. I have placed this as top priority of the problems to be solved and we are increasing our efforts in many fields. A study on officer recruiting within the Corps has just been concluded and we will be making a major drive through our Corps Contact Officers in Universities and Schools, by visits and lectures to these establishments, and by encouraging young men to come and visit our units. I would welcome any help from my audience as well as suggestions on how we could improve the flow of good potential officers. I think there is one factor where we may give a false impression to the young man. There is a mistaken but widespread belief that you have to be incredibly clever to be successful in the Royal Engineers. Of course, we do have the incredibly clever officer and we need him, but we have recruited in past years a proportion of high quality young men who have not been quite university material and I would like to go on encouraging such a proportion of our officer entry who have the potential to be first class officers as well as the intelligence and flair for practical engineering. Obviously I would prefer the good potential officer to have his degree but I do not think we should be exclusive.

I am glad to say that recruiting into the TAVR has improved and there have even been slight improvements in Scotland and Northern Ireland, both, until recently, difficult recruiting areas. All TAVR Units are now affiliated to a number of University Officer Training Corps or School Combined Cadet Forces as are their regular counterparts. I hope that this will have a marked effect on both TAVR and Regular officer recruiting in the future.

INFLATION

I think I should make mention of the effects of inflation and changing social times on the traditional pattern of military life of both our officers and our men. The rise in the cost of living and the restrictions on pay increases have affected our officers and men in the same way as they have affected the rest of the nation. I am aware that many officers and soldiers are purchasing their own houses as a safeguard against further inflation, and this together with other expenses such as school fees, despite Boarding School Allowance, places a heavy burden on family finances. As a result many wives now work to supplement the family income and consequently there is a changing pattern in the traditional social life of units which we have known in the past. I mention this subject because I believe that we should be aware of what is happening, and that we should all take account of these changes when we plan our future activities and budgets.

E-IN-C'S TOURS

On a more cheerful note, during the past months I have had the great privilege of visiting our sister Engineer Corps in Australia, New Zealand, India, Canada and the United States. Wherever I have travelled I have been met with the greatest enthusiasm and kindness and have been struck by the very distinct bond that links Engineers of the Commonwealth and our NATO partners. It was encouraging to see the varieties of the sapper tie worn with great pride in many of these countries and how they value their links with the Royal Engineers. Not only would I like to take this opportunity of thanking them for receiving me so well but I am sure that on your behalf I can say that we hope these links remain as strong as ever in the future.

ADVENTUROUS TRAINING AND SPORT

I have not had time this afternoon to give you full details of the adventurous and sporting activities of members of the Corps, whether they have been climbing Mount Everest, skippering the record breaking first leg in the Financial Times Clipper Race, being bitten by a Vampire Bat in the jungles of Panama or rowing for Cambridge in the Boat Race, regrettably unsuccessfully. We have won the Westminster to Devizes canoe race, as well as sending canoeists to Montreal for the Olympic Games. We also had representatives at the Winter Olympics, and, for the first time for some twenty years, the Army golf champion is a sapper. These are just some of the many achievements of the last year, and I am sorry that I cannot mention all the others individually.

I also only have time to briefly mention the work we are doing to encourage Corps enterprises, which we are hoping will continue to expand in the future. You will all know of the sad fire in the Headquarters Mess at Brompton and of the extent of the damage. We hope that the Mess will be fully repaired by May next year, and you will be aware of the Restoration Fund which has been widely advertised in the *Supplement* and elsewhere.

SUMMARY

In conclusion, the Corps is extremely busy and our commitments do not look like reducing. There are some clouds in the sky, mainly caused by financial and manning considerations, but these are challenges that we are meeting, and wherever I have travelled in the last year, and I have visited most units in the Corps, I have been struck by the enthusiasm and good sense of everybody, their acceptance of the need for change and for all the extra work that is involved. I can assure you that sappers are maintaining our rightful place in the forefront of the Army wherever we are and whatever we are doing.

Emergency Electrical Power Tasks in Northern Europe 1944/45

T G MARTIN, TD, CEng, FI Mech E, FIEE

THIS article is based on a lecture given to representatives of British Area Electricity Boards attending a course on War Emergency Problems of Electricity Supply, at the Home Office Civil Defence Staff College, in May 1967. The Author relates power plant damage problems to war damage in France, Belgium, Holland and Germany in 1944/45 when emergency power generation, transmission and distribution works were undertaken during military operations by 549 E and M Company RE in 21 Army Group.

"The Repair of Caen Power Station" by Lieut-Colonel A B Scrase RE was published in the RE Journal September 1946. There was also a reference to the generation and transmission work undertaken in "RE Work on the L of C with the BLA" by Brigadier R H Perry CBE MC in the March 1946 issue. This article is complimentary to both and deals with the subject from an entirely different point of view in a different way.

THE damage inflicted in Britain from enemy air attack produced no power dislocation on a scale comparable to that suffered in the North African, Italian, and North West European campaigns, nor the extensive dislocation which may be presumed to have occurred in Soviet Russia, but from certain of these tremendous theatres of war there is no doubt that some lessons can be learned for first stage solutions of power famine likely to arise after a nuclear holocaust in Britain.

In the case of North Africa the four campaigns there entailed virtually total destruction of all Public Utilities but power plants from Tobruk to Tripoli were small, the highest distribution voltage being 11 kV and restoration beginning in 1950 was under the auspices of the Libyan Government. Priorities were accorded to the Ruler's palaces, Government Offices, Water, Sewage and Hospital plants.

In the Italian campaign less than 10% of the 800 MW of central Italy was captured intact and restoration was entrusted to a variety of civil agents via an Allied Engineer Committee. Services assistance was comparatively simple—an example being the early power supply to Naples Water Pumps from three DC generators each of 600 kW rating, from Italian submarines, the DC being converted to AC at a tramway substation by inverting a convertor set.

In the North West Europe campaign however, apart from widespread fuel limitations, very extensive wreckage indeed occurred to generating plants also transmission

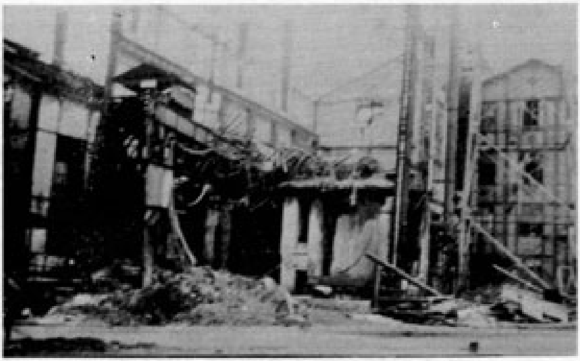


Photo 1. Caen Power Station, Main Structure before reinstatement

and distribution systems of four countries and this established urgent tasks for military engineers in a way which had not been foreseen in the campaign planning. Mobile diesel-alternators totalling 10,000 BHP and 280 miles of overhead lines were erected in various power tasks inclusive of the major projects which I shall describe. These referred to undertakings in Belgium, France, Holland, and Germany executed by 549 E and M Company RE of which I was Officer Commanding.

Initially the function of this Company was to provide water for the Army from the Normandy beach-head onwards. Power generation and distribution was of secondary importance at that time and was limited to quite small powers and medium voltage systems for such requirements as a base hospital, town water or sewage plant and the like. Then came a rude shock. You will recall the allied plan was to assault the ancient town of Caen which was served from the Channel by both canal and river. The Army's base port, after the temporary floating facilities provided by Mulberry Harbour, was to be this inland port of Caen and not Calais or any of the other heavily defended coastal ports. 10,000 tons of bombs from the air, reinforcing the Army's artillery and tank attacks, cleared the Germans from the centre of Caen town by mid-July 1944 but the prize—a port—was a mountain of rubble in places up to forty feet high and two miles of dock-side, lock gates, capstans, cranes, town water supply, rail and steel workshops, a very important oxygen plant, etc, were useless. Nothing could be put to use until substantial power was available.

Until the outbreak of war the Departments of Manche and Calvados depended on power imported from the South via a 90 kV grid system but this source had been interrupted for some time. The old power station retained for peak load use only had served since 1940 using two 16 MW and one 6 MW turbo-alternators. A fourth group had not been capable of running in recent times. Now, after much difficulty in gaining access over the rubble, the power station was a shattered nightmare of twisted metal in a roofless and wall-denuded structure. The French staff was either dead or missing. Little of the plant could be assessed technically until a Company of Pioneers had spent three weeks on clearance of rubble.

Damage was ultimately seen to amount to:—

(1) a blown-out building structure; (Photo 1)
(2) sheared foundations under one turbine and two rotary convertors;
(3) two boilers wrecked beyond repair;

Emergency Electrical Power Tasks
In Northern Europe (1)

(4) blocked and buried cooling water ducts;
(5) punctured and leaking oil tanks with consequential fouling of cooling water ducts;
(6) a crashed overhead travelling gantry which had destroyed one alternator exciter; (Photo 2)
(7) innumerable splinter holes in high pressure steam, also oil and water pipes;
(8) strained joints, fittings, and supports;
(9) destruction of control panel of an automatic Velox quick-steaming boiler;
(10) cable weakening from weathering;
(11) deliberate destruction of the cooling water barrage in the River.

As my Company was on the outskirts of Caen and since the Lines of Communication Chief Engineer knew that I was with Central London Electricity pre-war, I was asked to make a station reconnaissance with General de Gaulle's Engineer Advisor, after which I accepted a challenge to get one boiler and one turbo-alternator on docks' load in five months. To do this I asked for reinforcements of my unit. The Army was rapidly screened for officers and artisans with electric power training and experience. After quick re-arrangement I had a valuable platoon, all members of which had been pre-war employees of County of London Electric Supply Company, two electrical platoons and one workshop platoon also my original mobile workshops, crane, and other vehicles. I was then a Major and since I found myself directly responsible to the Director of Works Major-General—an unendurable impertinence in military command—the War Office was signalled to find a Power Engineer to come out as a Colonel to be interposed between the General and myself. The man sent was Norman Elliott, now Sir Norman, then Borough Engineer and Manager of Gravesend Corporation, supported by Louis Neville a Metropolitan-Vickers Turbine Engineer, also R Bannister of British Insulated and Callender Cables Limited, both of whom were gazetted Majors.

I had meanwhile prepared a plan and started work. The tasks I had set were:—

(1) to concentrate on one boiler and the 6MW turbine;
(2) to make and fix newly calibrated scales of British units on all instruments—the mental gymnastics for the men to interpret scores of metric scales was too much to contemplate;
(3) trace electrical faults of auxiliary plant and rectify them—tracing was a formidable task and demanded much patience. It was much more difficult because it was in exposed wet conditions;
(4) excavate the cooling water duct using mechanical equipment and reconstruct the heavy reinforced concrete structure. We had to call upon an Army Troops Company of Sappers to help in this;
(5) evacuate oil from ducts using self-priming pumps with specially shaped nozzles and flush into the River and the Canal alternately according to state of tide. This was a tedious business;
(6) overhaul the turbine, repairing its exciter, oil cooling and lubricating system, governor and auxiliaries;
(7) completely overhaul and test No 1 boiler including safety valves, water level alarms, pumps, motors, ID and FD fans, automatic stoker and the whole of the coal-handling plant—a task made especially interesting when we encountered hand-grenades and ammunition in the coal hoppers!
(8) weld and repair all pipes and fittings, blanking off to the destroyed items of plant;
(9) switchgear and control gear repairs;
(10) provide temporary shelter, pending a proper roof, over the selected turbo-alternator;
(11) clearance, repairs and maintenance in plant and buildings of power station precincts, eg the lime-soda water softening plant, overhead and underground coal transporters, artesian well make-up system, pre-heaters, de-aerators, etc;
(12) concurrently a great deal of work had to be undertaken after complicated

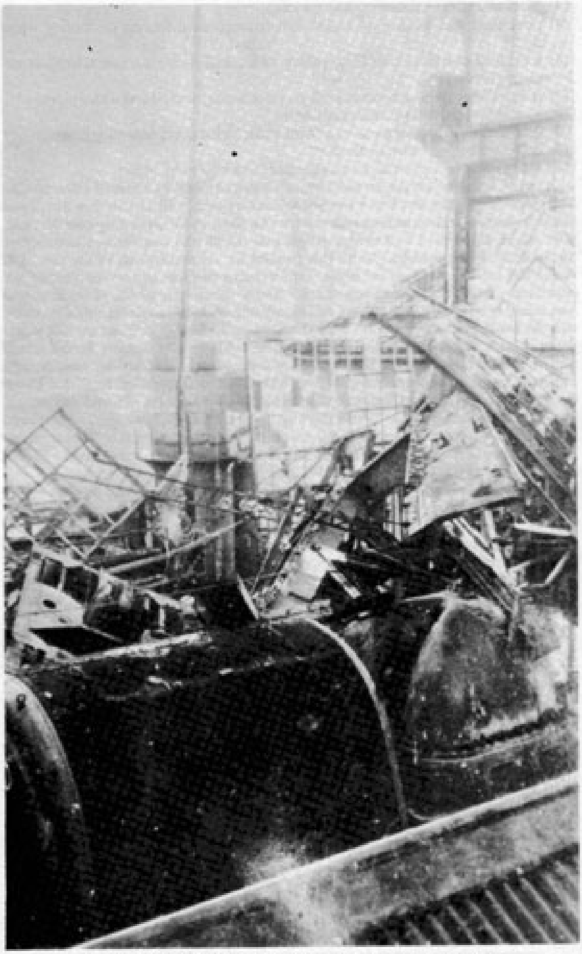


Photo 2. Caen Power Station, Turbine Hall before reinstatement.

Emergency Electrical Power Tasks
In Northern Europe (2)

search for inspection and test of the transformers, switchgear and cables of the distribution system in the docks and town centring on plants of top priority.

The whole of the French distribution staff appeared to be dead or missing.

Docks cranes fortunately needed few major repairs but had DC motors and the station converting plant was destroyed beyond repair. Arrangements to move a motor generator from Cherbourg failed on account of impassable roads. Then it was found possible to employ a Ward Leonard Set with a 2·8 kW motor and 440 V generator serving the complex auxiliaries of the Velox boiler. This sufficed for some DC supply, albeit with dreadful voltage drop, to docks cranes, the motor being fed from a British rail-mounted diesel alternator of 300 kW rating, (Photo 3), which we tied into station busbars. Later we supplemented the Velox motor generator by a British Mercury Arc Rectifier shipped from London Passenger Transport Board and we brought in more rail-mounted diesel alternators for primary supply.

Tracing, testing, and assessing the town distribution system occupied an enormous number of man-hours, for more than twenty sub-stations had been destroyed. The distribution system was re-fashioned with some trans-position of transformers, links, switchgear, line and cables, until several supplies were practicable on a wide basis of priorities. Simultaneously, with this town and docks work a substantial generating capacity was established from more rail-mounted 350 kW American and 300 kW British diesel alternators to supply enough power for auxiliaries to "get the station away" also to supply power via the improvised DC convertor for the docks cranes.

Work proceeding in the power station was not without its risks as autumn advanced and brought increasing rains. I recall an Officer and several of his tradesmen Sappers dancing an involuntary jig on the top of No 1 boiler eighty feet above ground when, in a downpour of rain, the building structure became energized from the 2·8 kV busbars. At all times after September it was cold as day and night work proceeded under only a little temporary cover.

Eventually No 4 turbine was coaxed and after a preliminary warm-up ran on house load thereby relieving some of the rail-mounted sets outside. The great days when we first paralleled the turbo-alternator with the external rail-mounted plants and when we exported energy into the town for the first time still recall excitement and gratification in my memory. But there were unpleasant hazards for unrevealed weaknesses from concealed blast or fragmentation damage made themselves known without warning as steam pressure, heat, or voltage stresses brought failures. There

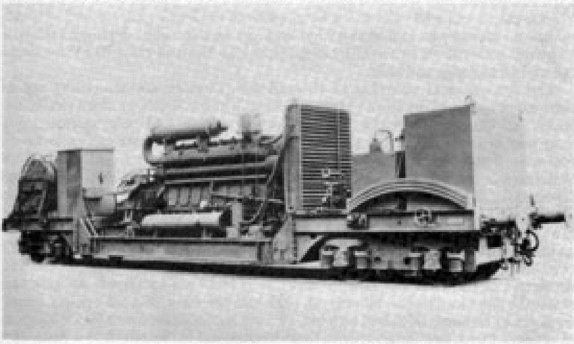


Photo 3. 300 kW rail-mounted Diesel Alternator (English Electric), one of several used in parallel for Caen Dockside Crane power and for initial feed into Caen Power Station.

Emergency Electrical Power Tasks
In Northern Europe (3)

were two serious electrical explosions and fires in the course of the work. Auxiliary switchgear failures and boiler superheater failures were particularly numerous and tiresome.

Finally the complicated Velox boiler reinstatement was undertaken; its gas turbine and circulation system were innovations to us and therefore instructive.

After only three months we were on load and two turbo-alternators and four boilers became available only two months later. Preparation of performance sheets, night procedures, air raid switching drills, emergency changeover drills, and standing orders for plant operation and maintenance were prepared and as a trickle of French Engineers returned we were able to hand over a ruin which breathed into 13·9 kV feeders to a limited town distribution system, which supplied 500 V DC to non-stop docks cranes, alongside which ships relieved Mulberry Harbour, which fed five 30 kV feeders strengthened by us for Bayeaux and other town supplies, also five 65 kV feeders ready for grid interchange in due course.

We did not wait to see Caen station recover its original load of 25 MW. By November 1944 new tasks were upon us, firstly at Calais. For all of these tasks in France and Belgium one or more of the rail-mounted diesel alternators and modest lengths of simple HT and LT cable and overhead line work linked into repaired local systems provided rapid and effective generating and distribution facilities for priority military and water requirements. These power demands varied from 500 to 2,500 kW each. So the Company with its workshops and transport was split into two or more parts separated by long distances with a section of diminishing strength left for Caen power station operation until March 1945. Handover there had been slow as it was found that deaths of colleagues, shattered morale, shocked and unfamiliarity with items of their own plant on load in a roofless broken building which took several subsequent years for complete rehabilitation, seriously weakened the capability of the French staff to control.

Though emergency generating tasks elsewhere, particularly in quarries worked for material for priority air-strips and road construction, continued to be entrusted to us it was a unique power transmission project which occupied our time predominantly for the first six months of 1945. This was on the Dutch/Belgium border north of Antwerp.

By the end of 1944 we had proved to ourselves, to Army Headquarters, and to the Civil Authorities that we could speedily undertake high voltage work of all kinds. We had even executed repairs on the lofty pylons of the French 220 kV grid of which we had no counterpart in Britain at that time. So we came to be deployed on a task to permit power to be exported from Belgium into Holland via a 70 kV overhead line we had to design and build.

The circumstances were that all Holland was powerless and the enemy was in occupation North of the Rivers Maas and Waal. On the South, or allied side of the Rivers, at Geertruidenberg, a fine new power station had been systematically destroyed by enemy marine engineers. The only remaining power station in South Holland—that at Nijmegen—was out of action in an operational area. With Walcheren in the west flooded by the British more power demand than normal was expected in Zeeland and the North Bravant provinces. Coal—normally from Germany's Limburg mines—was of course cut off. That winter saw the whole of Holland in a desperate plight. The scheme evolved to supply both military and civilian priority needs depended firstly on arrangement at Government levels for two American-built 25 MW floating power plants to be diverted to Ghent and Antwerp instead of the Far East for which they had been conceived. At these two places the American plants, burning oil, were to supplement Belgium's power supply from power stations which had very low coal stocks. Secondly a new 70 kV link was to connect Dutch and Belgium grids from Roosendaal in the North to a point east of Antwerp. At the Northern terminal a transformer sub-station was to be built. In the South a connection was to be made to the Belgium grid near Merxem power station,—a large station but partly out of action after V–2 rocket damage. Thirdly the Dutch system from Roosendaal to Geertruidenberg power station, together with associated HT feeders to towns of military and civil importance were to be built or repaired by Dutch civil and military engineers. The latter were equipped and trained quickly by British Royal Engineers and operated under guidance by a section of my Company. The damaged Roosendaal sub-station was converted into a sectionalising station and two new transformers each of 12·5 MVA rating were hurriedly made for us by ACEC at Charleroi. I well recall their installation, for with their cooling radiators and long bushings they were too tall and bulky for camouflage hence we were mortared, sustaining casualties among men and damage to the radiators which had to be replaced.

The overhead line we constructed was fascinating but difficult. It was built through lowlands country all the way for eighteen miles and occupied 232 timber pylons of "H" pattern. It was constructed in a long and bitter winter. It was built through the longest enemy minefield we had experienced. Each of these factors introduced problems unknown to us in transmission line experience in Britain.

As to the ground, Dutch and Belgian Engineers warned us we were attempting the impossible for the water table was only eighteen inches below the surface. We had to design and build pole bases to remain in water or running sand and we had to prevent the poles assuming drunken tilts when the frozen ground thawed out. Except for only forty impregnated seasoned poles from Belgian stock all poles were supplied by Canadian Forestry Sappers who felled them in forests far to our south. We obtained 0·1 ins², (7/·135), conductor copper from Britain, galvanized steel wire from Belgian shipyards, bolts in large numbers were made by my unit and we despatched vehicles through France to the works of Compagnie Electro-Ceramique at Tarbes in the Pyrenees bringing back the pottery's entire stock of string insulators—a memorable journey on which my Officer-in-charge spent only five francs as for the greater part of the route he was the only British Officer seen in areas liberated by Americans and Free French. There was no Common Market prejudice in those days! The exceptional demand for lifting tackle, cordage, shackles, blocks, etc, far exceeded Royal Engineer stocks hence we had to resort to local requisitioning in Belgium and France.

Pole transport was a great problem. No rail or road vehicles could accommodate poles of such lengths. Organizing pole transport through the low ground to their sites of use entailed employment of tank transporters, bulldozers, the Company

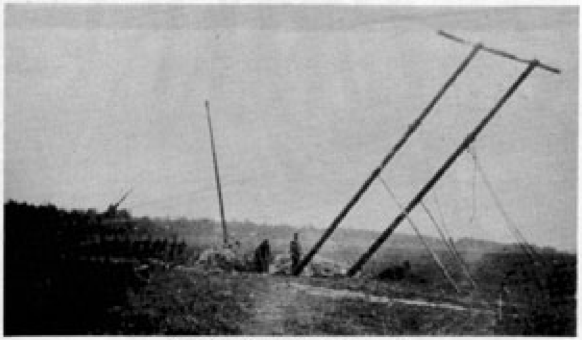


Photo 4. Pylon erection in Lowlands.

Emergency Electrical Power Tasks
In Northern Europe (4)

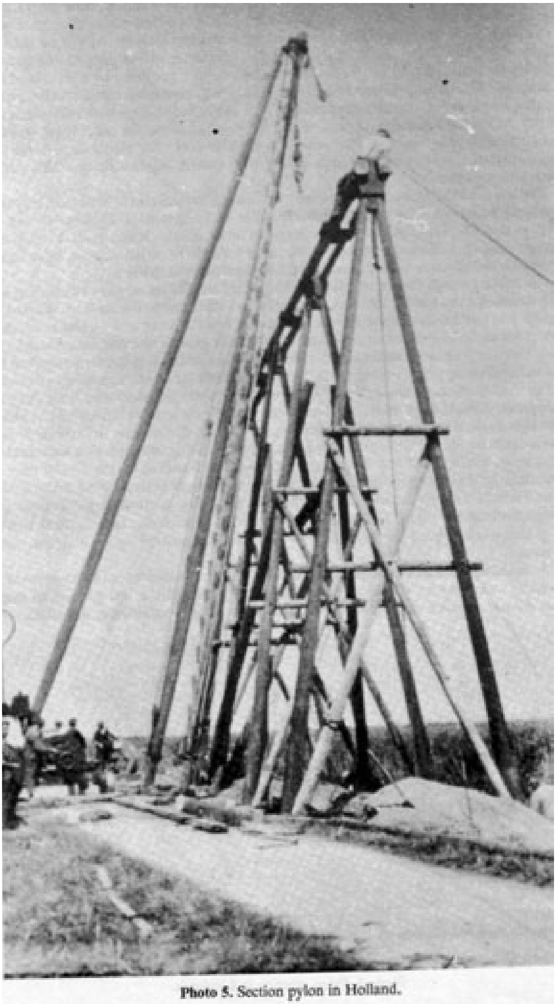


Photo 5. Section pylon in Holland.

Emergency Electrical Power Tasks
In Northern Europe (5)

mobile crane, special tackle in the endless ditches and culverts, bridging and, best of all, a Dutch horse-drawn vehicle known as an *orst*—hired with driver and animal—yet even this prized appliance was handicapped as the horse frequently sank up to its girth in bog. Our carpenters worked by the roadside stripping barks by adze and using power-saws for tops and bases of poles. Workshop fitters, blacksmiths and welders had work in abundance making clevis bolts, cross-arms and insulator bolts, etc, also base bolts three feet long.

There is no time to describe the designs adopted for bases, bog-shoes, kicking plates, bog rafts 15 ft^2, and built from 14 in diameter timbers with diagonal bracings below ground for angle poles—these were features of work and material not subsequently visible. Excavation was by hand, by 3 ft 6 in diameter Canadian mechanical auger and by well-sinking rig. An easy hole took a half-day; the worst occupied ten days. Centrifugal and reciprocal pumps, steel and timber skeining, traditional Sapper derricks, gins and tackle—all were employed. Snatch blocks for line-stringing and all other tools were conventional. An air pilot's view would have revealed the Company's advanced section, comprising surveyors, mine removers, and picket placers. The rearguard would be fixing cattleguards on stay-wires and erecting danger boards which we made and painted in Dutch and Flemish—including a magnificent sign over a canal crossing to warn Masters of large barges to lower masts.

I have referred to the minefield work. We had some of these to contend with in France but here we had thick minefields laid by the Germans in retreat, of anti-tank and anti-personnel mines in varying depths and very large numbers. Most were in improvised non-metallic casings of wood, concrete, glass and earthenware. They were in agricultural land, canal banks, bushes, trees, and bridle paths. Perhaps my happiest recollection arising from the difficulties of this lowland country is that of the splendid horses which had been stolen throughout France for use in a Senior German Officers' Leave Centre at Calais, captured by us and put to use by my Officers for supervision of the line construction. It was not possible to traverse much of this ground each day by either wheeled or tracked vehicles. And so, in World War 2, I had the privilege of making part of the Corps of Royal Engineers once more a mounted Corps and I enjoyed Edwardian pleasure from my indents for forage allowance.

The line entailed crossings over thirteen roads, thirteen LT lines, a canal, a river, a 50 ft wide so-called drain and telephone lines. Spans varied from 137 ft to 426 ft, the basic span being 400 ft. We adopted loading data normal for Britain. Pole heights were 43 ft 6 in to 50 ft. Operational hazards were frequent. We had casualties at Roosendaal from mortaring, but suffered only plant damage when engaged by German fighters *en route* for their last attack on Antwerp. Then we had some V-bomb damage and slight casualties from this and once also accidental American gunfire damage. It will be understood that though we were L of C Engineers we were operating in Divisional areas.

The floating power plants providing part of the power source to be exported were most interesting. They took three months to be towed across the Atlantic. One named *Seafire* was moored at Ghent and we linked it to Lagenbrugge Power Station. The second, named *Resistance*, was moored at Antwerp and was linked to Schelle power station. Control was co-ordinated by telephone line between Merxem (Antwerp) and Geertruidenberg power stations. Docks construction Sappers were responsible for building the dolphins and my Company provided terminal and feeder cable arrangements. We also had some 11 kV jointing work. Each floater was equipped with a 25 MW hydrogen-cooled turbine and two oil-burning boilers delivering steam at 850 psi and 900°F. An output transformer with multi-tapped series-parallel secondary winding permitted voltages up to 150 kV. Owing to the urgency and short term nature of the project no protective relay lines were run.

Space precludes more than the outline I have given of some of the emergency power work undertaken, all of it unforeseen, in the Continental disasters of 1944 and 1945. It is my belief that the lessons we learned do have some bearing on what could be short term emergency power demands if ever this country experienced widespread damage from nuclear war and this of course is the real purpose of delivering this address. In stating what I believe these lessons to be I must emphasize that I am not considering areas where plants may be intact and transmission and distribution systems may be good or may be fed by easily repaired grid lines to permit of the Board's standing emergency procedures. I refer to heavy damage areas where generating plants, transmission and distribution systems may be extensively destroyed and where overall administration is vested in a Regional Controller who finds his territory temporarily or permanently cut off from peacetime supplies. The first point is that demand is prescribed by a priority which is often different from what can be envisaged in peace-time and it is a demand which is defined by an overall controller and not by an engineer. You will remember that sewage and water pumps, hospitals, quarries, dock cranes and capstans, were among the first needs in my experience in addition to demands which were exclusively military. The second point is that where emergency works are in cities or towns the preliminary stage of structural or rubble clearance and the work entailed in tracing buried distribution through mountains of rubble can be onerous and distribution engineers can imagine how painstaking and utterly exhausting the latter work can be. The third point is that re-energizing cables which have been left apparently undisturbed or only slightly damaged but have had prolonged periods out of use can yield unexpected breakdowns. The fourth point is that even with good peace-time emergency stocks large-scale disaster throws up many vital requirements which can only be satisfied by others. It will be recalled that with all my equipment I had to make use of requisitioned materials from the Pyrenees to the United States. Horses, bulldozers, transporters, cranes, and many other appliances featured among my transport and most of these entailed extensive enquiry beyond our own field and the use of sanction by higher authority. In nuclear war even the well-equipped Area Boards would need to invoke similar aids through Controllers and Local Authorities for they cannot depend on self-reliance and use of their normal contractors' services.

Finally it will have been noted how very much improvisation characterized our work. Even with compulsory powers of requisition operative in several countries my officers and I had to employ our design knowledge for on-site fabrication of an endless variety of new medium-voltage, mechanical and structural equipment also

Photo 6. Typical rubble in Caen streets.

Emergency Electrical Power Tasks
In Northern Europe (6)

for amendments to high-voltage apparatus. Perhaps this could be the greatest problem for future generations in your service for more and more are we conscious of your dependence upon contracts of substantial magnitude and value which you place with contractors and manufacturers. Perhaps war disaster of the kind studied in this College may not be accompanied by perils from booby traps, mines, shells and the rockets of World War 2 but a sharp ground-burst nuclear attack could produce an acute power crisis requiring emergency solutions in many ways resembling those I have portrayed from events in history of not so many years ago.

Past to Present

BRIGADIER D L G BEGBIE, OBE, MC, BSc, CEng, FICE

MISTAKEN though it is to rush into print at the end of a long career, I have been persuaded to write as an article some of the thoughts prepared for a talk just before my retirement. In this I was to speak of the British Sapper and, by taking some pointers from World War II, sought to support my conviction as to the rightness of the present balance in the Corps between combat and professional engineering.

Like many others of the same age group, my career has always, in a sense, stood on its head in that we received a crescendo of intensive experience in the war years that was never, mercifully, to be matched again. Our formal training at University, on Supplementary Courses, and at the Staff College came afterwards. This was unfortunate but not necessarily absurd, as we could build by study from a solid foundation of practical knowledge, learning from readily understood and possibly shared mistakes.

Though I have some regret at having been unable to enter the Royal Military Academy, the "Shop", in 1939 because of its closure, I have none at having enlisted in the ranks in 1940. In the period until going to OCTU at the end of 1941, I avoided too easy a transition from school to officers' mess. I learned about soldiers, field engineering and musketry with a thoroughness that was ever after to serve me well, and something of the soldier's view and expectation of his officers and NCOs. By a wise decision, or by luck, I was sent from OCTU to take two recruit parties through their paces, consolidating my knowledge and acquiring the degree of confidence that I needed before going into action.

At the end of 1942 I joined a field company about to embark for North Africa. By this time units were composed mainly of wartime soldiers, with a sprinkling of regular and TA men. This gave the units two important features; the age bracket was eighteen to forty, blending zest for adventure with stamina and maturity, and there was a diversity of talent and experience. A similar sense of unity of purpose in pursuit of a national cause is not, of course, easy to attain in peace. Then as now, the Sappers drew from the brightest of the intake but many were already skilled or semi-skilled tradesmen. Most field engineering skills came easily to them, watermanship being a possible exception since the element was generally unfamiliar. On the other hand, deployment and battle drills required constant practice in all conditions, especially at night and in harsh weather. Even under the impetus of war, there was a degree of inertia to be overcome in taking seriously the practice of drills, such as harbouring, stand-to, protective digging, security of the site, gas alert, fire or boat drills. Fierce and determined trainers were a necessity. One such was our CRE. At the threat of the direst penalty, such as removal from the field force, he taught us, amongst other things, to be observant. Travelling anywhere became a hazard. As he sprang questions as to what had been seen of engineer interest, woe betide anyone whose mind had been diverted by passing fancy! And thus we learned, to our great subsequent advantage, the value of engineer intelligence.

And so to war at the turn of the tide. Now a united and trained team, albeit a little too green, we were faced at once with our first test. Torpedoed at night *en route* to North Africa, we had learned our raft drill, there was no panic in the unit, and we were all picked up. Re-equipped, we took part in three major battles in Tunisia, learning still at every step. When the campaign ended our field company was charged with preparing the destroyed port of Sousse for use by the invading forces for Pantellaria, and then Sicily. It had been effectively destroyed by German engineers and Allied bombing. No experts on hand, nothing like the 62 CRE (Construction) and 64 CRE (E and M) organizations of today. Ingenuity and determination alone would not have been enough in such a short time frame. The extra strength came from the hidden reserves in any wartime unit. In this case not so much the officers, but some of the soldiers who were skilled in the essential trades, such as welding, concreting, carpentry (for formwork) and masonry.

Very soon we, too, were on our way to the Italian campaign. Bridge building now predominated over mine clearing. There were no technical problems with the low level bridges over the wide stream beds, but the pier and abutment repairs benefited from the skills of our tradesmen. It was useful, too, to have men used to working at heights for some of the high piers. After the successful but unrewarding crossing of the Sangro, the company moved across to below Cassino for an FBE (Folding Boat Equipment) crossing of the Garigliano, making use, for the first and only time in our experience, of an intensive smoke screen.

Transferring, in January 1944, to take over a platoon in a field company in 56th (London) Division, I embarked with them that night in a landing craft bound for Anzio where the battle was going badly. I was struck at once by the tremendous influence for good on morale of the sergeant-major, a splendidly solid and rubicund figure with a silver mounted stick. In the next eighteen months he was to be wounded twice and each time to be sadly missed. Anzio was the crucible of my career. Under the determined leadership of our Canadian OC, the company was in every action during the next perilous six weeks, combining combat engineering with infantry work. We would have been decimated the night of our arrival had our harbour drills not been spot on and every man dug in regardless of his fatigue. In our last action at Anzio, the three depleted and diminishing platoons stood in line in defence to the West of the Flyover Bridge. By a combination of forward patrolling by night, defences in depth including mines and barbed wire, and well protected defensive positions, the company held its ground until relieved, and by then the German attempt to overrun the beach-head had been abandoned. Unlike a very amateur effort in response to an emergency in Tunisia the year before, we had learned to work with all arms in the defence. It has, on other occasions since, seemed to me that Sappers can tend to lead their lives in isolation and in a state of supposed self-sufficiency, whereas neither characteristic is entirely beneficial.

Then through the battles of the Gothic Line and the endless crossings of the lateral rivers on beyond. Teamwork getting better and better; the weather becoming worse and worse. One particular bridge, "*ITS-ON-ITS-OFF*" on Route 9, stands out from the others. Measured in a hurried and interrupted reconnaissance, we waited for nights to get up to build the 130 ft Triple Single Bailey. It was the most obvious of all bridge sites, totally exposed and the approaches raised above the surrounding ground. Unable to rehearse because of the apparent imminence of its construction, impossible to get to the site, my platoon built and re-built it mentally. Finally a warning order was followed by the go-ahead. The operation went like clock-work. Steady enemy shell-fire landed, miraculously, in a muddy field beside the site doing no harm. The Divisional Commander, accompanied by our South African CRE, came up on site as the bridge neared completion, to be greeted by an impressive display of shelling. He asked whether it was normal for work to go ahead without interruption, to which the reply was probably affirmative provided it was sensible so to do. In this case the bridge had to be open for the bridge-head supporting weapons to get across before dawn, and we knew that our luck was unlikely to hold. Sure enough as the last men left the site, the shelling moved right on to the vacated construction area.

On to the closing stages and the turning of the German line at the Argenta Gap. A successful crossing of the River Reno in which the intended surprise misfired. Three of our four company commanders wounded, together with the RSM, formerly our redoubtable sergeant-major. One of the company commanders was from the field park. As usual he, like his team, was supporting from the front, seeking means of shortening the time on the job, whether it was minelaying, preparing bridges for demolition, repairing damaged bridges, constructing command posts or whatever the task. The forward repair work of the plant troop and the bravery of the plant operators and of the bridging platoon were always outstanding.

The end came at Trieste. An immediate change of role to the rehabilitation of a damaged hospital, and to the construction of hutted camps and border posts. Again no RE Works Services experts on hand, but this time there were officers and soldiers in the unit with the experience and skills needed.

Before projecting my thinking forward to professional engineering in the Corps today, I offer two general comments. Our Sappers then, as now, were notable individuals, practical men who could use their heads and their hands, not easily deflected by the irritating habits of enemy and weather, cheerful men, taking quiet pride in their achievements. They expected, with every justification, that their officers should know their onions and lead by example. It was easy to regard such men with the trust and affection born of shared experience; and not for the officer to think or know whether these sentiments were reciprocated.

Looking back to those years and comparing our potential with that of today, it seems that one of the major differences lies in age and experience. We relied then on having mature tradesmen and professional engineers from civilian life in our midst. Recruits and officer cadets were taught only military training and field engineering. If we went to war now, there would not be a similar infusion of talent, and our TAVR elements are neither large enough nor organized in such a way that their talents could be spread throughout the Regular units. The Corps has to train its own Regular professional engineers and tradesmen in peace. The wisdom of the Corps' dual-trade training policy is confirmed on this count alone, added to which a man trained in an artisan trade is quicker to learn combat engineering and more versatile in its application. The possession of such skill is a contributory factor to the unique personal quality of the Sapper. On the other hand, the training of large numbers of professional engineers would be expensive in time and money, and the scope for practising their skill in peacetime is limited. The present modest numbers are probably about right to provide the professional leavening necessary to the Corps of officers and warrant officers trained and experienced in construction management and techniques.

In pursuing versatility, proved a necessity in war, there is always the danger of falling between two stools and being good at neither combat engineering nor construction. To be good at both requires organization and determination. I look forward to the introduction of the field squadrons (construction) next year since the commanding officers of the UK regiments, that will each include one such squadron, will be able to achieve a proper balance of capability and training and avoid, by judicious cross-posting, many of the peacetime frustrations of aspiring tradesmen or combat engineers, for example those returning from successful higher trade training.

The Corps has done well in increasing its involvement in support of the Property Services Agency. The only snags are that the tasks tend to be building construction and also that, whilst accepting that we must work within the framework of the PSA, this arrangement tends to absolve the Corps, undesirably, of total responsibility. Thus it is that the exercises in support of the Overseas Development Ministry are in many ways better. A unit is then entirely dependent on its own resources, having planned a project all the way through, ordered the stores, and assessed the finance. But here again there is a drawback in that units cannot be kept in these remote places for more than about three months, partly because they have operational roles elsewhere and partly because of family separation. Only with STRE (Specialist

Team RE) Malta is there the opportunity for a unit to exercise almost total responsibility for long term projects offering the widest scope of good class engineering. Then there is a separate scheme whereby some qualified individuals receive selected specialist continuation training with civil firms and public authorities.

These varying aspects of a total programme are designed, amongst other reasons, to give experience to those who have benefited from professional engineering and trade training courses. It is a programme conducted with difficulty and often misunderstood by the less well informed. But without it the worst evils of paper thin qualifications and thwarted ambitions would result, and, above all, in the strict engineering sense, there would be no truly qualified and experienced Regulars on hand in time of war. The indications are that, as the problems of war damage repair to communications and installations come under closer attention, the need for the professional leavening of experienced engineers and tradesmen will become greater still. The Corps will have to pursue its well-balanced course, and be neither perturbed nor deflected by critics whose opinions may not have been tempered first-hand by the sharp lessons of war.

Royal Military College, Kingston

No 2354 COLONEL H W C STETHEM, OBE, CD

Colonel Stethem is the Secretary-Treasurer of the Royal Military College Club of Canada, the Association of Ex-Cadets from the Canadian Military Colleges. He graduated from RMC Kingston in 1937, took a commission in Royal Signals, and served in the British Army until he returned to Canada in 1948.

1976 is the Centenary Year of RMC Kingston. To mark the occasion a few words on the Ex-Cadets who joined the Royal Engineers would seem to be appropriate.

Since 1880, 566 Ex-Cadets from RMC have joined the Regular Forces of the Empire and the Commonwealth, other than those of Canada. All but two of these joined prior to the end of World War II. By far the largest number (173) joined the Royal Artillery but 129, the second largest total, joined the Royal Engineers. However, the Royal Engineers did have many firsts.

In the first batch of five, No 13, A B Perry joined the Royal Engineers. Perry suffered a compound fracture to his right leg and on the advice of a medical specialist decided to retire from the Royal Engineers. He later joined the Royal Northwest Mounted Police and in 1900 he became its Commissioner. He remained Commissioner until 1922 when he retired. The last survivor of the first batch through Kingston, General Perry died in 1956 at the age of ninety-five.

The first to die in the Service of the Empire was No 39, Captain H B Mackay, DSO, RE. Captain Mackay took part in the Bechuanaland Expedition of 1887–88. He was mentioned in dispatches and won the DSO. He was the first Ex-Cadet to win this decoration and the fourth to be mentioned in dispatches. Unfortunately during this campaign he contracted West Coast Fever from which he died in 1891. The first to be killed in action was No 62, Captain W H Robinson, RE, who lost his life while, with conspicuous bravery, blowing in the gate of the stockaded village of Tambi near Sierra Leone on the West Coast of Africa on 14 March 1892.

The first Ex-Cadet to be knighted was No 147, Colonel Sir Percy Girouard, KCMG, DSO, who graduated from the College in 1885 and joined the Royal Engineers in 1888. In 1896, he went to the Sudan where he became Director of Railways and constructed and operated some 600 miles of railway for the Dingala Expedition and the Sudan Campaign under Lord Kitchener. In 1898 he was made President of the Egyptian State Railways and Telegraphs and the Port of Alexandria.

For his services in the Dingala Campaign, Lieutenant Girouard was awarded the DSO, the third Ex-Cadet to win this honour. In 1899 he became Director of Railways in South Africa and served on the staff of three successive Commanders-in-Chief, Sir Redvers Buller, Lord Roberts and Lord Kitchener. He rebuilt and controlled some 5,000 miles of railway and, for his highly valued services, Captain Brevet Major Local Lieut-Colonel Girouard was created a Knight Commander of St Michael and St George in 1900, at the age of thirty-four. Girouard remained as Director of Military Railways for South Africa until 1902 when he became Commissioner of Railways for the Transvaal and Orange River Colony, a post he held until 1904 when he returned to Regimental Duty in England. In 1907, Churchill, then Under-Secretary of State for the Colonies, sent for Girouard to ask his advice on the construction of railways in Northern Nigeria. Churchill offered him the post of High Commissioner and Commander-in-Chief of Northern Nigeria and promised him a free hand to deal with the problem of railway development there. Girouard accepted and he remained in this appointment until 1909, at which time, he was made Governor and Commander-in-Chief of the East African Protectorate. In 1912, he resigned from this appointment, retired from the Service and became a Director of Armstrong, Whitworth and Company. He returned to the fold for World War I and in 1915 was made Director-General of Munitions and Supply in London and was granted the local rank of Major-General. He died in 1932.

The first to attempt to climb Mount Everest was No 758, Brigadier Sir Edward Oliver Wheeler, MC, late RE, who joined the Mount Everest Reconnaissance Expedition as a surveyor and photographer in 1921 and used photo-topographical methods to make a detailed survey of the Tibetan side of the mountain. This required establishing stations between 18,000 and 22,000 feet. In 1923 he joined George Mallory (who lost his life on the mountain in 1924) and G H Bullock on the first ascent of the North Col (23,000 feet). He discovered the feasibility of the route along the East Rongbuk Glacier which became the route for all subsequent pre-World War II Everest Expeditions. He later became the Surveyor General of India. Knighted in 1943 for his services in World War II, in World War I he won the MC, Legion of Honour (5th Class) and was mentioned in dispatches seven times. He retired in 1947, returned to Canada, founded the Canadian Alpine Club, and died in 1962.

First to be mentioned in dispatches nine times was another engineer officer, No 171, Brigadier-General W B Leslie, CB, CMG, who graduated from RMC as BSM (the senior cadet rank) in 1888, was commissioned in the Royal Engineers and returned to RMC Kingston as an RE officer to teach Military Engineering from 1895 to 1899. His first two mentions in dispatches came during his service in East Africa (Somaliland 1902–04) and the next seven in World War I where he served in the Dardanelles, France and Flanders, much of it with the ANZAC Corps, first as an AA and QMG, then as their Chief Engineer and finally as the GOC of the 1st Australian Infantry Brigade. He remained with the Australians until June 1918 when he became the commander of the 190th Brigade.

First to reach the rank of full general in the British Army and the first to become Colonel Commandant of the Royal Engineers was No 138, General Sir George Macaulay Kirkpatrick, KCB, KCSI, who was appointed Colonel Commandant in 1927, and representative Colonel Commandant for the years 1934 and 1935. Gazetted to a commission in the RE in 1885, he saw service in many parts of the Empire, in the South African War and World War I. For four years prior to World War I he was the Inspector General of the Australian Military Forces and during World War I he became the Chief of the General Staff in India. Following that War he served as General Officer Commanding His Majesty's Forces in China and later again in India as General Officer Commanding in Chief Western Command. He retired as Colonel Commandant in 1939 at the age of seventy-three and died in 1950.

The last Ex-Cadet from RMC to serve as Colonel Commandant of the Royal Engineers was No 729, Lieut-General Sir A E Grassett, KBE, CB, DSO, MC, who was commissioned into the Royal Engineers in 1909. Sir Edward served in the Irish troubles in 1914, in World Wars I and II, and in the Waziristan operations on the North West Frontier of India in 1921–23. Promoted to Major-General in 1938, to be General Officer Commanding the British Troops in China, he returned to the UK before Japan entered the war in 1941 and was shortly afterwards promoted to Lieut-General. In 1944–45 he was Chief of Staff for Civil Affairs in SHAEF. Following the war he became the Lieut-Governor and Commander-in-Chief of Jersey. He served as Colonel Commandant of the Royal Engineers from 1945 to 1955. He died in 1971.

The long association between the College and the Royal Engineers is one of which we can be proud.

It Was Not His Day

MAJOR J T HANCOCK, RE

There can be few Sapper officers who have not experienced one of those days when everything goes wrong. If they were unlucky their OC, or at worst their CRE, happened to be around at the time. In 1814 Captain Frederick English had a run of bad luck over several days of bridging. He not only had the Duke of Wellington and a whole army watching every move, but also a bright young Sapper Subaltern who reported his misfortunes in two letters to Lieut-Colonel J F Burgoyne.[1]

Captain English was twenty-four years old and had six and a half years service as a Sapper. He had taken part in the first Peninsula campaign in 1808, when he was present at the battles of Rolica, Vimiera and Corunna. He did not return again to Wellington's army until January 1814, when he was placed in charge of the Pontoon Train. The Subaltern was Lieutenant Peter Wright, an experienced Peninsula officer, since he had served under Wellington since November 1810. He had been employed in the Lines of Torres Vedras, had taken part in all three sieges of Badajoz as well as that of Ciudad Rodrigo and had been attached as a divisional engineer officer throughout the advance into France.[2]

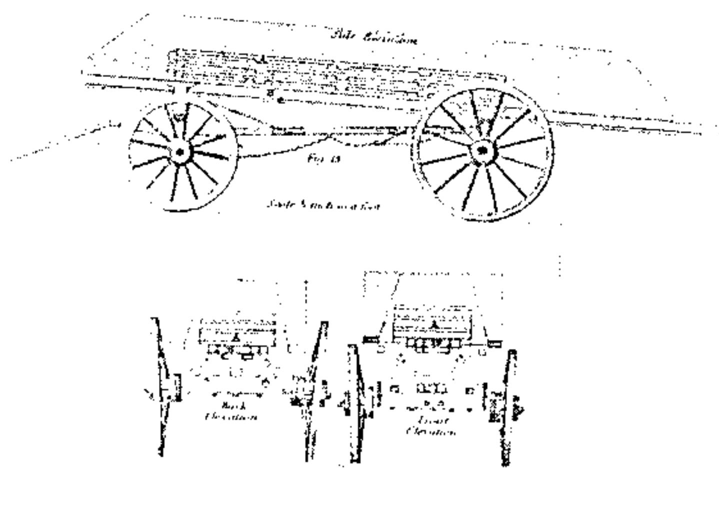
A Pontoon Train normally consisted of forty pontoons, of which four were regarded as a reserve. They were undecked, straight sided, rectangular in shape, with nose and stern at an angle of 45°. They had a light wooden frame which was covered with a double skin of soldered tin. Each pontoon moved on its own four wheeled carriage with its share of decking, anchors and cordage etc. The total weight of pontoon, decking and carriage was 35 cwt and this was pulled by six horses. Also in the Train were forge carts, rowing boats to help with the construction, tool and store carts.[3]

The standard method of construction, was to row across two "sheer lines" which were then fixed to pickets or trees and hauled taut using capstans. The pontoons were rowed or punted into position, at 10 ft spacings, and moored bow and stern to the sheer lines. Where the river current required the use of anchors, these were laid upstream to each pontoon. Baulks were passed across the pontoons and bolted together to form four rigid road bearers. These were covered by chesses and gangboards to form the roadway. Allowing for landing bays, thirty-six pontoons at 10 ft spacings could bridge a river about 125 yd wide.[4]

There are many theories and arguments about Marshal Soult's and Wellington's aims and intentions at Toulouse, but the basic facts are quite clear. Soult concentrated the majority of his men in the fortified town and its surrounding area. The town lies within a complex of rivers and at least one of these had to be crossed in any attack by Wellington, so that pontoon bridges were essential to the allied army.

The approach march, to Toulouse, was the first of English's problems. The Quartermaster General, Major-General Sir George Murray, noted that there were considerable delays in the march of the pontoons, which were partly due to the poor state of the roads.[5] The Judge Advocate General, on Wellington's Headquarters, records that on 26 March it was "entirely rainy, and our road was, perhaps, as bad as any we have ever passed with artillery, and that is saying much. The troops were splashed up to their caps, and hundreds were walking barefoot in the clay up to the calves of their legs for about five miles, whilst the best of the road was like that to Hounslow in the worst season after a thaw. - - - - - - To give you a notion of it, I may mention that Lord Wellington's barouche was three hours stuck fast in it at one place; one hind wheel up to the axle, the other in the air. No one was in it except General Alava, who was unwell. I left them endeavouring to move it by means of four artillery horses, in addition to his own six mules, but in vain; six oxen in addition at last got it clear."[6] The problem of moving forty pontoon carriages with their supporting carts, can easily be imagined.

Wellington had decided to make his initial threat to Toulouse from the south, so English's first bridge was to be across the Garonne at Portet on the night of 27 March. Bridge site recce was not entirely a Sapper officer affair, since officers of the Quarter-master General's staff were frequently employed on this task. It is fairly certain that English, occupied with his problems of moving the Train, was not the officer to select the site. In the first of his letters, Lieutenant Wright records that the pontoons marched from Muret at 8.0 pm and arrived at Portet at about 10.0 pm. It was fortunately a fine night, but the Garonne was flowing very rapidly at the bridge site. Wright was not taking part in the actual bridge construction, but was to cross with about 400 men to occupy the opposite bank and cover the operation. It was intended that he would row across in pontoons, while English started his bridge. In Wright's own words, "The whole of this plan was very shortly knocked on the head; English first sent his jolly boat with the sheer line; whether from mismanagement or the rapidity of the current, the boat went down the river and it was about an hour before it could be brought up again. They then tried the thing over again, and with the same success. It was then thought wise to go higher up the river and at last they fastened it to the other bank. Unfortunately the rope instead of swimming down the river stuck so fast at the bottom, that it was a full hour before they could get it loose, and it then



The Peninsular Pontoon

Fig 1. Reproduced from Major-General Sir Howard Douglas' *Essay on the Principles and Construction of Military Bridges and the Passage of Rivers in Military Operations* (1832 Edition).

immediately stuck again in the same kind of way. When it first got fast at the bottom I tried to persuade English to place two or three pontoons under it, some distance apart, in order that the rope might be floated; however they were afraid that the pontoons might be lost in so rapid a current. At last after sticking at it for two or three hours or more they tried this plan and succeeded in stretching the sheer line across after five hours hard labour." With the sheer line across they could measure the width of the river and found that it was 159 yd wide. Since they only had 133 yd of bridge they gave up the possibility of bridging that night, repacked their stores and left. Wright states that "Lord Wellington was not very much displeased", but Major George Napier of the 52nd Foot records that "Lord Wellington was furious. I never saw him in such a rage, and no wonder; for this unpardonable mistake was the cause of many days delay."[7]

It was not until the night of 31 March that a second attempt was made to bridge the Garonne. This time the site selected was near Roques, so that Sir Rowland Hill's corps could cross and seize the bridge over the Ariege at Antagabele. Wright reported that "English commenced the bridge immediately after dark, but from the rapidity of the current, the clumsiness of the workmen and from two or three little accidents, the bridge was not complete until daylight." Hill crossed and successfully seized the bridge at Antagabele but found the roads so bad, from the recent rains, that Wellington had to order him to return. Hill re-crossed the pontoon bridge on the night of 1 April and it was then taken up and repacked on its carriages.

Frustrated in his attempts from the south, Wellington now decided to try the north. Staff and Sapper officers were sent out to recce for bridge sites. Wright states that it was he who found the most suitable spot about "half a league" from Grenade. He suggested to Wellington that a bridge should be constructed in daylight, when it could be completed in two or three hours less time. The bridge was started at daylight on 4 April and it must have been a great relief for English that 125 yd of bridge were completed in four hours, although the current was very strong and the approach road for the pontoons very difficult. The 3rd, 4th and 6th Divisions crossed the bridge with their artillery and some cavalry. However, by the afternoon English's misfortunes started once more, when rain began to fall heavily and the Garonne began to swell. The bridge swayed with the rapid current and before dusk some of the cavalry had to dismount and lead their horses across in single file.[8] Once more Wright records the disaster, "English thought it best to take up everything except the pontoons which were well secured by sheer lines and anchors. The bad weather now appeared to have set in and on the 5th, the river still continuing to swell, English took away four or five pontoons from the centre. The sheer lines immediately fell in the water and one pontoon was sunk by the weight of the sheer line. Lord Wellington, who was on the spot, ordered the whole to be taken up." The pontoon had not in fact been sunk but floated away down river. Another Sapper officer, Lieutenant Reid, galloped to Verdan and offered a reward of £5 to any of the locals who would stop the pontoon and bring it ashore. The pontoon was found and returned to the Train on 6 April.[9]

Three divisions were now separated from the remainder of the army by the Garonne, but Soult made no attempt to take advantage of this promising situation. It was not until the night of 7 April that the floods subsided. On the morning of the 8th, English was able to relay his bridge and two Spanish divisions crossed to join the British divisions on the other side of the Garonne. At about 1.0 pm a brigade of Portuguese artillery was crossing when the last pontoon sank under one of the guns. The gun fortunately reached the landing bay and was safe, but there was a two hour delay while the pontoon was dragged out of the river, turned upside down to drain out the water and replaced in the bridge.[10]

Hill's corps and the Light Division still remained on the west side. Wellington planned to keep Hill's corps on the west side for the attack on Toulouse, but decided that the pontoon bridge was too far north. He ordered it to be moved to a site nearer Toulouse, to shorten the line of communication between the two parts of his army.

The new site was near Ausonne and it was intended that the pontoons should be taken up during the night 8/9 April and relaid by 9.0 am. The misfortunes of English now reached their climax. Once more, Wright records his discomfiture; "English was the whole night taking up his bridge and did not reach the spot appointed until 9.30 am. Lord Wellington was in a most violent rage, told English that he had never done his duty, and put him and the whole Train under the orders of Captain Greene of the Artillery,[11] who had been previously placed there to take charge of the Artillery horses. English unfortunately had left the jolly boat and sheer line until the last, and they unfortunately lost their road and did not arrive until 12.0 o'clock; the bridge in consequence was not completed until 3.0 pm. The movements of the army were thus stopped until the following day."

The Light Division crossed the new bridge and the battle of Toulouse took place on 10 April. Soult withdrew into the city of Toulouse and escaped to the east on the 12th, before Wellington could complete the investment of the place.

Lieutenant Wright was killed while on a recce before New Orleans on 30 December of that year. Captain English was more fortunate and continued to serve in the Royal Engineers and was promoted to Lieut-Colonel on 10 January 1837. Bad luck struck again on 16 May 1849 when he attended a trial of a new gun battery made of asphalt, at the Royal Arsenal at Woolwich. During the trial he was struck by splinters from the battery which broke his arm, caused subsequent paralysis and he died on 30 June at the age of fifty-eight.[12]

It is said that one of the advantages of regimental history is that in adversity, the knowledge that previous generations have endured and survived is an aid to morale. The next time things go wrong, remember English and perhaps it will help to cheer you up.

Post-mortem Notes

Captain English cannot write his version of this series of disasters. It is only fair, therefore, to look into some of the reasons for his apparent failures.

The British Peninsula Pontoon was much the same, in design, as those used in the middle of the 18th century by Marlborough. Most continental armies had long ago realized their limitations and replaced them with larger, boat shaped pontoons. Our pontoons were very unwieldy and their box like shape was totally unsuited to use in wide, fast flowing rivers, where they easily filled with water and sank. With a width of 4 ft 10 in and centre to centre spacing of 10 ft, the surface flow of water was reduced to nearly half of the river width. This placed a considerable strain on the bridge structure as well as the anchors and sheer lines. The Garonne had a bottom of shifting, coarse gravel in which the anchors dragged and left the bridges mainly held by the sheer lines.[13]

The Pontoon Train was not formed, as a unit, until 1813. Although Pasley's school had been started in Chatham in 1812, the main aim in the first few years was instruction in field fortifications and there was no training for pontoneers. The Pontoon Train was therefore manned by Portuguese seamen who had gained a reasonable amount of experience during the war. There was no British pontoon bridging manual and from an examination of the career of English, there is no indication that he had previous experience of this kind of work.

The equipment had been in an appalling state as late as May 1813. The pontoons were not new and although they had new bottoms, the sides were battered and decayed.[14] Both pontoons and carriages gave trouble on the rough tracks over which they had to travel. On 11 May 1813, Wellington wrote to Earl Bathurst and reported that "We have been sadly delayed by the bridge, without which it is obvious we can do nothing. The equipment is quite new, and has marched only from Abrantes; but there has already been much breakage, and I understand that the carriages are shamefully bad. The truth is, that English tradesmen, particularly contractors, are become so dishonest, that no reliance can be placed on any work, particularly in iron, done by contract."[15]

The problems and the shortage of pontoons, for a wide river, had been pointed out to Wellington by Colonel Elphinstone, the Commanding Engineer. There was little that Wellington could do about it, but at least he might have made allowances when difficulties arose. He was not a man to suffer reverses quietly and English was not the first officer, by far, to suffer his displeasure.

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Joint Professional Meeting

DEEP DIVING TECHNIQUES

MR R GOODFELLOW, BSc, CEng, MICE, F Inst Pet, SPE, MBIM, Dip PH, MIPHE, General Manager and Director of Comex John Brown presented a paper on Deep Diving Techniques to a Joint Meeting of the Institutions of Civil Engineers, Mechanical Engineers and Royal Engineers and the Society for Underwater Technology at Chattenden Study Centre on 1 April 1976. Over one hundred and fifty attended including many wives.

Major-General J C Woollett CBE, MC, President of the Institution of Royal Engineers, was in the Chair. Introducing Mr Goodfellow General Woollett commented that Mr Goodfellow was standing in for Mr Bevan who was to have stood in for Mr Lloyd the original speaker!

Mr Goodfellow explained that he would try not to include over-complicated and specialized technical matter in his talk in view of the many ladies present. In setting the scene he would briefly comment on the history, physiological restrictions and in-water hazards facing the diver. He would then comment on what could be achieved by the diver and the costs involved.

In his introduction Mr Goodfellow said that without divers there would be no oil from the sea. In 1964, when 120 ft was considered to be deep diving, there were only about 200 divers, world-wide, who could be classed as proficient at that depth.

In 1976 there were about 1,000 divers employed on tasks at depths of 400 ft or more. This was a frightening expansion.

The first part of the paper summarized the state of the art for all intervention techniques and compared the advantages and disadvantages of manned and unmanned systems. In his more detailed comments. Mr Goodfellow explained the techniques of "bounce" and "saturation" diving. A typical sequence in bounce diving would be to have a diver working, at say 400 ft, for thirty minutes followed by twelve hours decompression. The preferred technique at these depths was saturation diving when the body of the diver was subjected to the working depth pressure before diving ("saturated" in effect). Under this technique very much larger periods of work at depth could be achieved and although a long period of decompression was necessary it was very cost effective. The toxic and narcotic effects of the constituents of air mixtures were explained, techniques had been developed to cover depths up to about 1,200 ft. Beyond this depth the physiological problems were very great and investigations were currently in hand to develop more sophisticated pressure suits for divers and to examine the effectiveness of liquid breathing.

Mr Goodfellow emphasized that it could never be overstressed that diving was only a method of arriving at the worksite. The diver must be able to perform certain artisan tasks but much of his usefulness lay in visual observation. This ability to see could be partly replaced by manned submersibles, for example, pipe line inspections, monitoring of cathodic protection systems, inspection of damage. Submersibles will always have limitations however and cannot entirely replace the diver in the "visual" role.

In conclusion Mr Goodfellow outlined four main factors to be considered in deep diving techniques. These were considered in short term of five years and long term of ten years. Firstly, planning the development of deep diving techniques in association with the planned development of oil field exploration; secondly, the training required for the necessary number of divers to balance the planned development; thirdly, the consideration of the engineering techniques of submarine exploration and development up to depths of 1,500 ft; and finally, research into the deep diving techniques envisaged at depths up to 2,000 ft.

The paper was illustrated by film and slides. The film concentrated on drilling off the coast of Labrador where the conditions were quite appalling.

The discussion which followed concentrated on four areas, training of divers, the trade skills needed by divers, the deep limits of oil exploration and extractions and medical problems.

On the training of divers to dive to great depths Mr Goodfellow emphasized that training could not be considered in isolation—selection was equally important and that selection took place after each stage of training. Training was progressive. In general terms out of fifty selected volunteers forty would be discarded as unsuitable after the preliminary tests. After a further four weeks only five would be allowed to continue training. A three month course would fit the five for simple diving and stand-by duties. After about two years of experience without much responsibility, diving up to 200 ft, then selectively on bell diving, the five would become qualified medium depth divers. It was from these divers that the deep divers were selected, a lot was known about them at this stage and they would be divided into mixed, bell and saturation type divers and given intensive training in their particular speciality. The divers started at about twenty-one years of age, at about twenty-eight the suitable ones became Superintendents and at about thirty-five years of age they were finished as divers. The selection and length of training and time to gain experience was a big worry. In the last year in the North Sea alone the number of divers had risen from 200 to 1,000. This meant that some lacked experience.

On trade skills Mr Goodfellow stated that they started off with selected skilled craftsmen and technicians and trained them to dive. The whole system of their operations depended on team work to get the right craftsmen to the right place at the right time (supported by the right men), to perform the task required.

On the depth limits and indeed on all environmental limits it was difficult to give a simple answer. Oil exploration was in the centre of a triangle the three sides of which were political, economic and technical. It is not a question of finding oil, it must be found at a depth which permits extraction. The present effective depth is about 1,000 ft moving up to 1,500 ft. New techniques would soon make 1,500 ft fairly common. Beyond this the engineering of the divers equipment would need a new approach.

Most of the medical questions and answers were beyond the comprehension of your reporters! Mr Goodfellow described the problems of aseptic bone necrosis but in answer to one question said that some people, not associated with diving, were susceptible to this. Within the industry divers were now carefully checked medically to ensure that bone marrow complaints did not exist prior to diving training; regular medical checks during employment ensured the continued health of divers within the boundaries of known medical science. This may not be enough. We had all heard about the high pay the divers received, up to £240 per day, but this was per day on deep diving and no diver did more than about twenty such days in a year largely on medical safety grounds as known.

Mr Gourley, Secretary of the Society for Underwater Technology proposed the votes of thanks; to Mr Goodfellow for his fascinating yet terrifying account of the deep sea; to Commandant RSME for making available the facilities of the RSME; the President of the Institution of Royal Engineers and to Captain Sedman RE who had "managed" the Meeting with such effectiveness.

After the Meeting some 120 retired to the bar and buffet supper and continuing discussion. Without doubt the combination of four Institutions/Societies with their different approaches to a common subject stimulates discussion.

Joint Professional Meeting

THE MAKING OF THE M3

ON 13 November 1974, at a Joint Meeting of the Institutions of Civil and Royal Engineers, the Royal Engineers presented a paper on the construction of an earth road in a developing country. It demonstrated the way in which we, the Royal Engineers, are able to plan and execute such a task, in a military environment, in a very short space of time.

In contrast, the motorway programme in England is being planned and executed by six regional Road Construction Units of the Department of the Environment. The procedures are much more complex; the country more developed; the finished product more sophisticated; the time scale for design and construction is longer and the costs, per mile, are much greater.

On Tuesday 30 March 1976 at 1800 hrs a further Joint Meeting was held, chaired by Mr Malcolm Cooke (FICE) of the Southern Association of the Institution of Civil Engineers where members of the South Eastern RCU, under their director Mr Brian Edbrooke, presented three papers showing some of the features of design and planning of motorways, with particular reference to the M 3.

Mr William S Pomphrey, BSc, MICE, SERCU HQ, opened the proceedings with "Planning and Design". In the historical background to the project we learned that the original scheme was "born" in 1937, since then there have, of course, been changes in concept and no doubt there will be more before the road is finally completed. Mr Pomphrey dealt first with Route Selection, Feasibility Plans and Public Consultation. He emphasized that although the latter was a time consuming process it was considered that public consultation in the early stages was likely to benefit both the public and the Department by providing an opportunity for public opinion to influence the choice of route before Public Inquiries were held. In dealing with

Design Criteria he referred to changes in standards of Motorways which affected the M 3 which was built in sections at different times. He explained the Statutory Requirements and the Publication of Orders. It is only after this stage, which included the Public Inquiries, could the detailed design be finalized, contract documents prepared and land entry effected. He explained the formation of the RCUs and how they worked in co-operation with the County Surveyors.

Mr J N P Cronshaw, BSc, MICE, MIHE, Hampshire Sub Unit, SERCU, dealt with "Bridgeworks in Hampshire". In his area there were fifty-four bridges. It was important that a major effort was made to develop design which would allow frequent repetition of type with consequent design and construction savings. He dealt with Highway Loading and described the principal structural types and costs. Space precludes descriptions of all the types which ranged from prestressed beam and slab continuous, thro' composite slabs of steel frames to *in situ* RC slabs. Many of the bridges were skewed (maximum 53 ft) but only one bridge presented real problems. Whilst under construction this bridge showed cracks which were caused by misalignment of the upper tendons! The remedial action which was very successful was described.

Mr N A Trickett, MICE, Chief Resident Engineer, Surrey Contract 2, was to have presented a paper but unfortunately was indisposed, and his colleague Mr Mike Walton stepped into the breach and spoke on "Construction in Surrey", a twenty-mile length of road let under two separate contracts. He concentrated his remarks in the main to the construction of the earthworks and motorway pavement. On both contracts the hauls of site-arising materials were long which dictated to a large extent the planning concept for construction. The total volume hauled on the two contracts was in excess of 5 M cu yds. He described the nature of the soils and the plant used (at one time on Contract No 2, at the peak of the earthmoving, the largest fleet of dump trucks in Europe was used with an average haul of seven miles). He spoke of some of the special problems faced and in particular on dewatering and the covering of water filled gravel pits. The latter involved suction dredgers and a resident team of divers.

Mr Walton concluded by emphasizing that it had only been possible, in his and the two preceding talks, to describe a few of the interesting features in the planning, design and execution of a modern motorway in this country. With changes in planning requirements an even greater length of time would elapse between the first Feasibility Studies and the final opening date, standards were changing all the time, as were techniques and costs.

Following the presentation of the papers some lively discussion took place covering all aspects of the presentation. Mr Cooke declared the meeting closed at 2015 hrs and following a vote of thanks by Colonel Bill Harrison many members moved to Minley Manor for a buffet supper where discussion continued until a late hour. The meeting was very well attended with some 200 members present—evenly divided between both the Institutions.

Ritten Kwik Kwiz—1

1 There have been six kings of England called George—name the other five.

2 Do you understand Newton's Law of Gravity? Answer Yes or No.

3 Who built the great pyramids—McAlpine, Wimpey, Pharaohs or Costain?

4 In the 1976 Irish Sheepdog Trials, how many dogs were found guilty?

5 Spell the following—(a) cat (b) dog (c) pasquinade.

Solar House Heating in Britain

LIEUT-COLONEL J M GUYON, MA

Capital letters refer to notes at end, arabic numerals in brackets to "line" in Table III

INTRODUCTION

THE search for alternative energy sources is now becoming urgent since this planet will have to rely on *income* once the *capital* is spent unless atomic comes to the rescue in time—which cannot be guaranteed. It is a characteristic of most income energy that it is best collected in penny packets, rather than at huge central stations, and used where made. Over one-third of all the energy we use at present ends up in the home in any case, which makes the home a good starting point for energy saving. This article aims to stimulate constructive thought and experiment.

ASTRONOMICAL

Earth circles the sun at a radius of about 93M miles at which distance the radiant energy is worth 1·36 units/m²/hr (kilowatt-hours per square metre per hour). A satellite in a shadow-free orbit could collect 33 units a day above the air, taken as ten miles thick. A cloudless bright June day at Kew (lat 51) would give 1·02 units/m²/hr under an imaginary vertical sun, 0·95 at actual midsummer noon sun altitude 62°, when the rays must traverse eleven miles of air, but only 0·25 at midwinter noon sun altitude 16°, when the rays must traverse thirty-five miles of air before reaching the surface. The loss is due mainly to water vapour in our oceanic climate. Chile, Australia, and the lands around the Persian Gulf, being much dryer, give much higher values at the surface. Smoke, mist, haze, fog and cloud reduce the value still further, as do local shadows—drastically.

Our axis of rotation is inclined 23½° to the plane of our orbit, so causing the sun's apparent track across the sky to change day by day and hour by hour, giving sixteen hours of daylight in Britain in summer, but only eight in winter.

The radiation consists of ultraviolet (wavelength 0·32–0·40 microns), visible light (0·40–0·75), and infrared (0·75–1·10), of which visible light carries only half the total energy. Most of the UV is absorbed above the planet's surface, one sunburns quickly and badly on a high mountain, but the IR penetrates cloud. The afternoon temperature on the most miserable sunless winter day is still higher than in the small hours of the morning. All three degrade to heat when they fall on a dark coloured surface. If there is enough light to take a photo with an ordinary camera, then some energy can be collected.

The effect of latitude is to change the sun's noon altitude by 1° per degree of latitude so that the noon June sun stands at 64° in the Channel Islands (lat 49) but only at 52° in the Shetlands (lat 61). The effect of longitude is to delay local noon sun time by four minutes per degree West of Greenwich, so that in Donegal sunrise, noon and sunset will be half an hour later than London. British Summer Time means that local noon sun time at Greenwich is at 1300 hrs clock time in summer, 1200 hrs clock time in winter.

GEOGRAPHICAL

The places in Table I lie in the same latitude belt as Britain (50–60) hence get the same amount of sun power year round on clear days. The table may serve to explode a few myths about our climate. Only two places out of the ten have less cloud, the rest the same or more. In summer only one place is hotter, the rest the same or cooler. In winter only one place is as warm, the rest colder or much colder. So although we get no more daylight than the penguins, the Eskimos and the Muscovites, our prospects of harnessing the sun are better than theirs.

Of sunshine falling on meadowland, only 1% goes into photosynthesis, yet this small fraction feeds the world. British farms and gardens are among the most productive on the planet. Conservatories, sunrooms, greenhouses, and cloches help speed

TABLE I—CLIMATE (A)

Place	*Temperature °F*		*Mean Annual Cloud %*
	Midwinter	*Midsummer*	
Britain	40	60	55
Moscow	0	60	55
Lake Baikal	0	60	45
Kamchatka	10	50	55
Alaska	32	50	75
Lake Winnipeg	0	65	45
Hudson Bay	0	60	55
Labrador	10	50	75
Falkland Islands	40	50	75
Heard Island	30	45	65
Campbell Island	32	50	75

plant growth by extra warmth. Glass passes incident radiation of short wavelength, but blocks re-radiation of heat at long wavelengths.

CLIMATIC

As every peripatetic artist and photographer knows, the quality of light in Britain is different. About 60% of all the light we get from the sun is diffused; our distances are bluer. The best days for collection are those very bright clear ones when the sun glares from a dark blue sky and one can see great distances; these often happen in winter in cold weather. The worst are those cold grey days when the overcast may be many thousands of feet thick and one needs electric light indoors. A surprising amount of heat is collected on days when the sun never appears. In every month of the year, there are days which belong climatically to a season *six months* away. The writer remembers vividly a picnic on New Year's Day in brilliant sunshine when one felt too hot in normal clothing. Many will remember the frost and snow in June 1975. Sun power collectors may "sulk" for days on end at any time of year and are quite capable of producing a burst of energy in December. Although one may attempt to reduce the British climate to tidy average figures to please the scientist, one must always remember that the average month or the average year is quite unreal and never experienced in practice.

COLLECTION

There is a French solar furnace at Odeilo in the Pyrenees where a battery of sun-seeking plane mirrors reflect the sun into a large fixed parabolic mirror: it cost £3M. A sun-following parabolic reflector, provided it could be kept polished, would produce considerable heat at the focus, as would a large glass lens—but very expensively. A trough collector, shaped like a small radiant electric fire, tilted once a month but otherwise fixed to face South would collect and concentrate most of the noon heat fairly efficiently. But all concentrators suffer the fatal defect in Britain that only about one-third of the available radiation can be brought to a focus; the remainder is omnidirectional and cannot. Flat plate collectors have been in use in Arizona for more than forty years, over a million are installed in Japan, and they are also used in Australia, Israel, and Cyprus. Major Christmas (B) used one in Jamaica and Brigadier Stewart (C) in Egypt; both households reported enjoying unlimited free bath water year round. American experience although voluminous is largely irrelevant to our peculiar climate. A few results for comparison are given in Table II.

THE DEVIZES EXPERIMENT

Fired with enthusiasm by Brigadier Stewart's article, and having been concerned in the old Ministry of Supply with the procurement of one hundred collectors for troop trial in Egypt and Cyprus (where are the results?), the writer built a model installation hoping to show that:—

(a) Useful heat can be collected in Britain even in midwinter by a flat plate collector aimed at the winter sun,

TABLE II—COLLECTOR PERFORMANCE

Name	*Place*	*Latitude*	*Altitude (Equinox)*	*Slope*	*Collection*
Christmas	Jamaica (B)	18	72	0	1·79
Stewart	Egypt (C)	30	60	60	1·09
Fitzmaurice	Cyprus (D)	35	55	30	0·87
Heywood	London (E)	51	49	40	0·73
Guyon	Devizes	51	49	70	0·69

(b) Risk of boiling or scalding in midsummer may be disregarded owing to the steep collector slope,

(c) Risk of freezing is also negligible given efficient gravity circulation through large pipes,

(d) A steel plate is just as efficient for this purpose as silver, copper or aluminium and much cheaper given a sound design,

(e) The corrosion risk may be disregarded at these low temperatures given mains water of average quality,

(f) A simple direct self-regulating system would work perfectly well without attention or adjustment.

The panel, one yard square, was made by White of Cowes and consisted of a flat face painted black with a corrugated sheet seam welded to the back so forming waterways running vertically into manifolds top and bottom (see Fig 1). This was erected on brackets to face true south, slope at 70° to the horizontal and tilt 10° sideways to provide a high corner for the warm flow water and a low corner for the return. The 2 in polythene pipes with 2 in of lagging were led into the bathroom and connected to a lagged five gallon store with normal cold feed and expansion pipes plus a draw off tap over the tub (see Fig 2). A water meter was fitted to the household's (three adults five children), full sized cylinder cold feed to find the draw-off pattern, and one gallon was run off the model tap into the tub at times to correspond, seven gallons being drawn off daily (roughly 1½ times store capacity). Thermographs, on loan, measured temperatures for a year at collector inlet/outlet, store top/middle/bottom, cold feed, and ambient air near collector (outside) and store (inside). A typical day's record is shown in part at Fig 3 and results for the year in Table III.

Weighing results against objectives:

(a) Heat can be collected in Britain in midwinter but it is low grade heat at a low temperature. More energy could be collected by a bigger plate but the temperature would remain low and would need boosting for domestic use. This is because plate

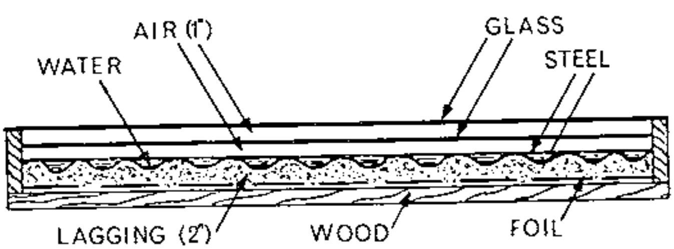


Fig.1 COLLECTOR SECTION

losses rise with temperature and even with double glazing the winter balance point is pretty cool in our climate,

(b) The highest store temperature achieved was 134°F on 8 July: an average year might have given 143°, and an exceptionally hot one, such as 1975, perhaps 170°. This is certainly hot, but not dangerously so,

(c) There were several periods of frost, the longest ninety-six hours continuously below 32°F with a minimum air temperature near the collector of 23°F. No ice formed anywhere in the system. This is because water at 40°F is at its maximum density and water cooler than this is lighter and therefore rises up into store, being replaced by warmer, but heavier, water from store bottom. A pond freezes from the surface downwards, sparing the fish at the bottom. A concrete garden pool in North America should have 2 × ½ in steel reinforcing rings right round the top to contain the ice pressure, and be 2½ ft deep so the fish live through the winter (F),

(d) No controlled experiment has yet been done and published to prove the superiority of the expensive high conductivity metals for this purpose so far as the writer knows. Black plastic is used for swim pool heaters with fair results at low temperatures. Devizes results are very similar to the late Prof Heywood's (E)—the only series yet to have been carried out in Britain on a scientific basis and published.

(e) No trace of corrosion damage appeared anywhere in the system over a period of fourteen months continuous operation on ordinary mains water. In most contemporary standard systems a steel boiler feeds hot water through copper pipes without disaster, but an aluminium collector would raise problems,

(f) A system intended for domestic use should be cheap, simple, reliable and look after itself. A direct gravity system without electrics or valves or chemicals meets this need well; it has stood the test of time and is still used in nearly all standard house hot-water systems today. It feeds the heat collected into store at a rate sensitively and

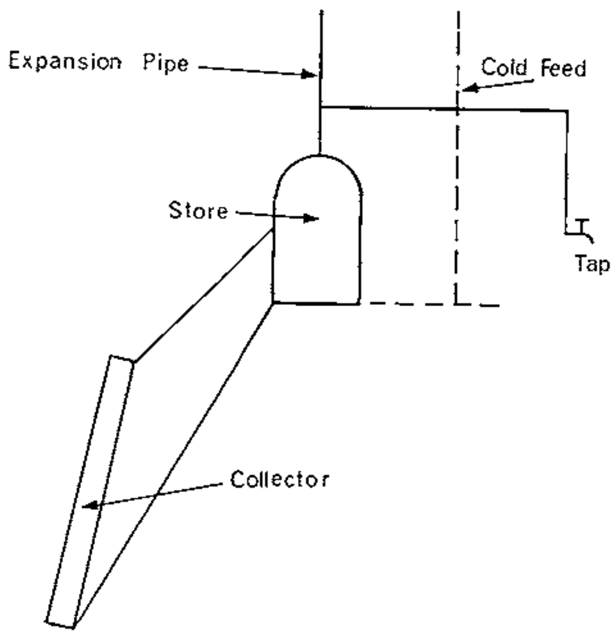


Fig. 2 PLUMBING

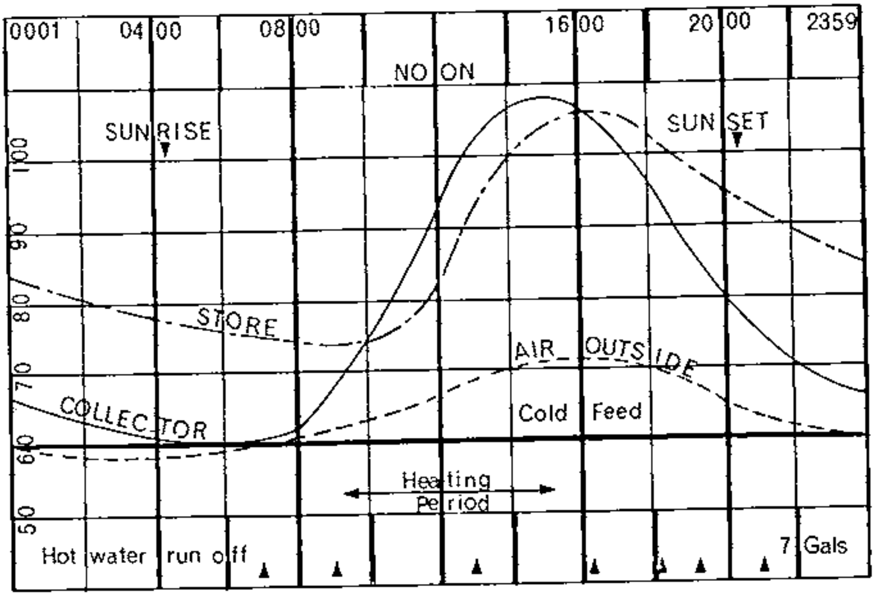


Fig.3 TYPICAL TEMPERATURES

TABLE III—COLLECTOR PERFORMANCE

Flat plate, glazed, bearing 180°, slope 70°, Lat 51, mid-Jun to mid-Jun.

SOLAR MONTH	DOJ Dec	JON Jan/ Nov	FLO Feb/ Oct	MES Mar/ Sep	ANA Apr/ Aug	MIJ May/ Jul	JUJ Jun	Table notes
1 Kew measured energy units/m²/ day	0·48	0·60	1·19	2·27	3·10	4·23	4·47	
2 Kew measured sunshine hours	33	43	71	133	142	206	202	(a)
3 Lyneham measured sunshine hours	31	63	86	113	147	211	188	
4 Deduced energy at Devizes	0·45	0·88	1·44	1·93	3·21	4·38	4·15	(b)
5 Day length sunrise to sunset	7·17	8·02	9·34	11·3	13·5	15·2	16·5	
6 Energy collectable in 6 hrs	0·38	0·66	0·95	1·03	1·45	1·75	1·53	(c)
7 Remaining energy (4 minus 6)	0·07	0·22	0·49	0·90	2·06	2·63	2·62	
8 Direct sunshine collectable (40% of 6)	0·15	0·26	0·38	0·41	0·58	0·70	0·61	
9 Reflected bright sunshine (10% of 7)	0·01	0·02	0·05	0·09	0·21	0·26	0·26	(d)
10 Sun's noon altitude A°	16	19	29	40	51	59	62	
11 Radiation normal to noon rays (8/sinA)	0·54	0·79	0·77	0·64	0·74	0·81	0·70	
12 Obliquity B° between rays and plate	4	1	9	20	31	39	42	
13 Unidirectional energy on plate (11 cosB)	0·53	0·79	0·75	0·60	0·64	0·62	0·52	
14 Diffused collectable energy (60% of 6)	0·23	0·40	0·57	0·62	0·87	1·05	0·92	
15 Omnidirectional energy (14 + 9)	0·24	0·42	0·62	0·71	1·08	1·31	1·18	
16 Total energy on plate (15 + 13)	0·77	1·21	1·37	1·31	1·72	1·93	1·70	
17 Average year would give 7% more than 16	0·82	1·30	1·46	1·40	1·84	2·08	1·82	(e)
18 Measured energy collected (collector part-shaded)	0·38	0·58	0·63	0·73	0·80	0·82	0·90	(f)

19 Estimated energy collectable (no shade, average year)	0·55	0·82	0·90	1·03	1·14	1·18	1·28	
20 Collector efficiency, actual % (18 v 16)	50	68	66	79	66	61	75	
21 Collector efficiency possible (19 v 17)	68	63	62	73	62	57	59	(g)
22 Cold Feed water temperature °F	46	46	48	54	56	58	59	
23 Measured top store temperature (30 day average)	60	69	74	83	88	92	96	
24 Temperature rise actual	14	23	26	29	32	34	37	
25 Best 3 rises (mean)	37	50	57	54	56	66	58	(h)
26 Worst 3 rises (mean	6	5	8	8	11	7	10	(i)
27 Top store temperature possible	80	102	111	125	134	141	149	
28 Cambridge average evening temp	38	39	41	46				
29 Temperature difference (65°F inside)	27	26	24	19				
30 kW to maintain 29 (150watts/°F)	4·1	3·9	3·6	1·5 (j)				
31 Units/month for space heat (from 30 @ 10hrs/day)	1230	1170	1080	450				
32 Units/month for store heat loss	200	200	200	200	200	200	200	
33 Total units needed	1430	1370	1280	650	200	200	200	
34 Boiler output 27m² (from 19)	440	670	730	840	920	960	1030	
35 Heat balance (from 33, 34)	−990	−700	−550	+190	+720	+760	+830	
36 Temp of water in store °F, resulting from heat balance (35) by *months*	Jan 118 Feb 100 Mar 103 Apr 115 May 128 Jun 142 Jul 155 Aug 167 Sep 170 Oct 159 Nov 147 Dec 130							
37 Cheapest alternative fuel £ (see Fig 5) £77·70 pa	3·5	5·4	5·8	6·7	7·4	7·7	8·2	

Notes

(a) June was less sunny over experimental period
(b) Lyneham is nearest Met Station to Devizes, which is eleven miles South of Lyneham
(c) Search cone apex angle limited to 90°, remainder being lost by reflection off glass
(d) Collector starts warming up 2½ hours before direct rays reach plate (see Fig 3)
(e) Measured sunshine hours both at Kew and at Lyneham were 6% below average over experimental period
(f) Eaves shadow of next-door house did not clear collector until noon, losing an estimated 25% radiation (undirectional)
(g) The fact that the average collector efficiency of 63% is higher than that normally accepted for flat plate collectors in Britain may, if true, be due to:—
 (i) Double glazing
 (ii) Collector design permitting almost continuous contact between the heat collecting surface and the working fluid behind, unlike the more usual tube-on-sheet designs
 (iii) Lower water temperatures, hence lower losses, due to large pipes, steep plate slope, and possibly double glass

and, if false, to:—
 (iv) Understating collectable radiation

The variation from month to month is probably due to energy difference between Devizes and Lyneham, eleven miles apart
(h) The best 3 days in DOJ produced as much heat as the average for JUJ
(i) There was no day in the year which failed to produce a rise in temperature
(j) Half month (arbitrary choice of length of heating season)

automatically attuned to the very variable rate of receipt, which a pump and on/off thermostat could not. Every time a hot tap is turned on, any water in the boiler which is warmer than the cold feed replacement will automatically be transferred to store and banked; this could happen in the middle of a warm June night and represents a heat gain. The four evening baths (Fig 3) are replaced with water from the collector warmer than cold feed. Given free circulation the system is inherently proof against freezing, thus avoiding the cost and complexity of an indirect system carrying expensive antifreeze plus concomitant corrosion inhibitors. Provided the collector top is at least 1 ft below the store bottom, reverse circulation at night or in cloud is automatically prevented: unless this is done, heat will be drawn from store and re-radiated by the collector acting in reverse. This can be used in hot climates to cool the house, but in Britain is to be avoided.

Mistakes—The collector was wrongly installed, pointing 7° West of true local South: the effect was to shift the heating period twenty-eight minutes later than planned as may be seen from Fig 3; this is not thought very serious. The collector flow and return pipes met the manifolds at right angles; due to plate slope this caused water traps near the collector, the effect showing as a "kick-start" 0900–0930 local sun time instead of a smooth curve; it is thought much bright interval heat was thus lost through not being banked in time. Store lagging was quite inadequate to cope with the boiler-off period of eighteen hours in every twenty-four. This did not affect results shown in Table III which are measurements of energy received and temperatures achieved, but would give the domestic user a very wasteful boost bill, particularly for early morning baths.

CURRENT EUROPEAN ACTIVITY

DOE funding through Central London Polytechnic and Milton Keynes Development Corporation has built a house with about 30m² of collector sloped at 30° to test for domestic hot water and space heat. The report is expected this year (1976). The Building Research establishment is planning to build a solar house for research this year (1976).

The Minister of Energy plans to hold a comprehensive conference on alternative sources this year: his Ministry is planning a thorough R & D programme using Harwell.

Wates have built three houses at Croydon with 144 ft² of collector acting as domestic hot water preheaters. The occupants are expected to move in about mid-year and have agreed the system be monitored over two years.

Pilkington in conjunction with the local authority are experimenting with tack-on sets for council houses in the Merseyside area.

A UK Section of the International Solar Energy Society with HQ in Australia (I) has been formed as has a Solar Energy Trade Association (M). It is estimated that about one thousand collectors were installed in Britain during the hot summer of 1975.

Experimental low energy or zero energy houses have been built and are under study at Aachen (Philips) Malmo (Swedish Government) and Lyngby (Danish Government) (N).

COLLECTABLE RADIATION

Without a private planetarium and computer and several months concentrated study of weather records, it would be difficult to calculate the radiation available at any one place in Britain. Sunshine % of possible varies from Eastbourne 41, Fowey 37, Cambridge 33, Perth 30, Eskdalemuir 27 to Baltasound 23 (J); so the probable result depends very much on where you live. Table III attempts an estimate, starting from the long-term measurements made by Kew for every hour of every day, and ending with the sort of temperatures which might be achieved in Devizes in an average year with a proper full size installation free from shadow and from mistakes (27).

Any reader wishing to follow through the Table needs to know first that a Solar Month is defined as a period centred on the twenty-first day of the calendar month and running from the sixth day of the same name month to the fifth day of the following month, thus corresponding roughly with the periods of the summer and winter solstice and the vernal and autumnal equinox, and enabling Solar Months with roughly equal mid-month noon solar altitudes to be paired, so reducing the size of the Table. The Solar Month JON pairs January with November and so on, DOJ & JUJ remaining single.

DOMESTIC HOT WATER

In the Devizes experiment the meter showed a consumption of 12 gall/head/day (the small twin daughters shared a bath) of hot water at 140°F. Today with softened water, detergents, and wash machines with their own built-in boosters 120°F is probably hot enough in a properly designed installation with the hot-water using appliances closely grouped round the store to minimize dead legs. The German and Danish houses permit 45°C & 43°C minima for domestic hot water (DHW) (N)—about 113 & 109°F—which bears out this line of thought. Given sufficient storage and really efficient lagging, at this temperature 80% is free from the sun (27) and only 20% must be boosted. The higher the temperature found to be necessary, the higher the boost cost and the lower the proportion supplied free by the sun.

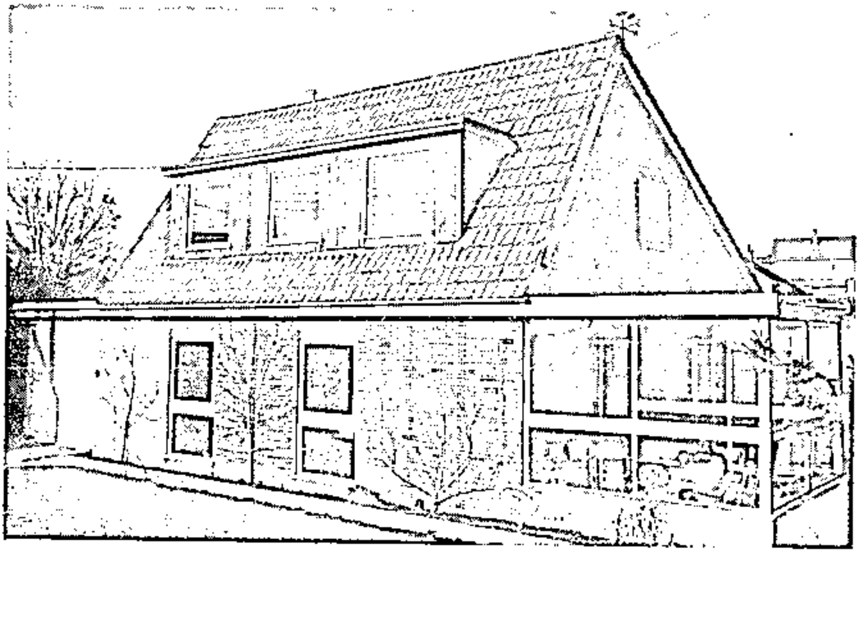
It will be seen from Table IV that the quantity of "hot" water needed for a satisfactory tub depends on the climate, the "cold" water temperature, the tub, and the individual, as well as on the hot water temperature. At 120°F more "hot" water will be used than at 140. The quantity needed can be dramatically reduced by using showers (5 gall *v* 20 gall) and spray taps (½ pt *v* 1½ gall). Requirements are compared in Table V.

TABLE IV—THE LONG BATH

Place	*Temperature* °F	*Quantity* gallons	*"Hot"* T	Q	*"Cold"* T	Q
Jamaica	100	20	130	8	80	12
Egypt	105	20	120	14	70	6
UK solar	110	20	120	17	52	3
UK normal	110	20	140	13	52	7

TABLE V—HOT WATER WEEKLY (GALS)
(2 ADULTS 2 CHILDREN)

Item	*Number*	*140 °F*	*120°F tub*	*120°F shower, spray*
Baths	28	336	560	140
Wash hands	112	168	200	7
Laundry	1	10	12	12
Dishes	7	70	85	85
Total Week		584	857	244
Total Day		83	122	35
Per head per day rounded		20	30	10



So if you want the sun to produce as much as possible free, you should seriously consider reducing both temperature and quantity used. This can be done without loss of comfort or hygiene.

The London Heating Centre estimated in 1970 that the normal heat loss from the domestic cylinder including boiler flow and return pipes was 17½ units a day. In 1976 the tenant of the Milton Keynes House was told by the experimenter that with 1 in of urethane foam round his cylinder, he was losing 3 units a day from his electric immersion heater; he is now putting on 3 in. "Quos Deus vult perdere prius dementat" (Whom the gods wish to destroy, they first make mad).

THE INSTALLATION

For the standard household (two adults two children) 122/35 gall for tub/shower daily must be heated in DOJ from 46°F (22) to 80°F (27)— the maximum possible on average in the coldest month of the year—by the sun: this needs 41,000/12,000 BTU or 12/3½ units which can be produced by a collector of area (19) 22/6 m². The house in the photo is known to the trade as a chalet bungalow; the strip of roof under the dormers has an area of about 8 m² sloping at 60°; if the dormers were abolished and the rooms end lit, the whole front roof so freed would have an area of about 40m²; the back roof has an area of about 75 m² sloping at 30°. So the "shower" household's boiler could quite easily be fitted as a tack-on set on top of the existing tiles below the dormer windows. The "tub" household would have to think of structural alterations or a purpose-built house—hardly worthwhile for hot water alone.

The solar boiler is on for six hours a day 0900–1500 local sun time and off for eighteen. Most hot water is drawn in the off-period (Fig 3) so heat loss becomes the prime target. A sphere presents least surface and may be made of anything watertight and strong enough (fibreglass?) to store the heat collected. A tub/shower household will need a substore holding 20/5 gall artificially boostable to 120°F when necessary for domestic use. The best arrangement is the ball and teat shown at Fig 4. The cold feed delivers straight through to the bottom of the boiler and only enters the store if the boiler contents are colder; they will usually be warmer, see Fig 3. The boiler flow enters the store on the equator, since it may be hotter or colder than store and needs to find its own level with least churning up of contents. If the twin nozzle shown does not do the job, a Dutch experimenter has used a very light flexible tube which automatically floats or sinks to the correct stratum as soon as the flow starts. A baffle with very small perforations is fitted on the equator to help preserve separation between the hot water at the top and cold at the bottom during the small hours of the morning. The warmest water in store at any time will always automatically gravitate towards the teat ready for boosting (if necessary) and use. The teat is covered with a dewar flask—an inverted oversize thermos jar—worth its cost in overnight heat loss prevented, hence cheaper morning baths every single day of the year.

The sphere capacity should be two days supply at least and preferably three (366/105 gallons, tub/shower) with at least 4 in fibreglass lagging properly applied. The object is twofold—to provide a small "flywheel" to carry over short sunless periods, and to make sure the store's thirst for heat is never fully satisfied and it can always swallow a little more: too small a store would quickly attain the top temperature and, by heating the plate, lock out further supplies of free radiation in afternoon bright intervals following lunchtime draw off.

The store needs a base booster, a deputy sun, to heat the top half or third to 100°F if the sun has not. Figures are averages and the sun may fail on any day of the year; the mean of the best three days temperature rise in DOJ (25) were as good as the whole of JUJ on average (24) which emphasizes the point. The bottom of the store is left cold for the sun to heat free tomorrow—why pay to heat it today? The deputy sun comes on guard at 3 pm when the solar boiler goes off, takes the temperature at the bottom of the top half or third and cuts in if it is below 100°F, cutting out when 100°F is reached and going off guard at 9 am when the solar boiler comes on again. If the family go away and shut off the booster then at the worst after a week's

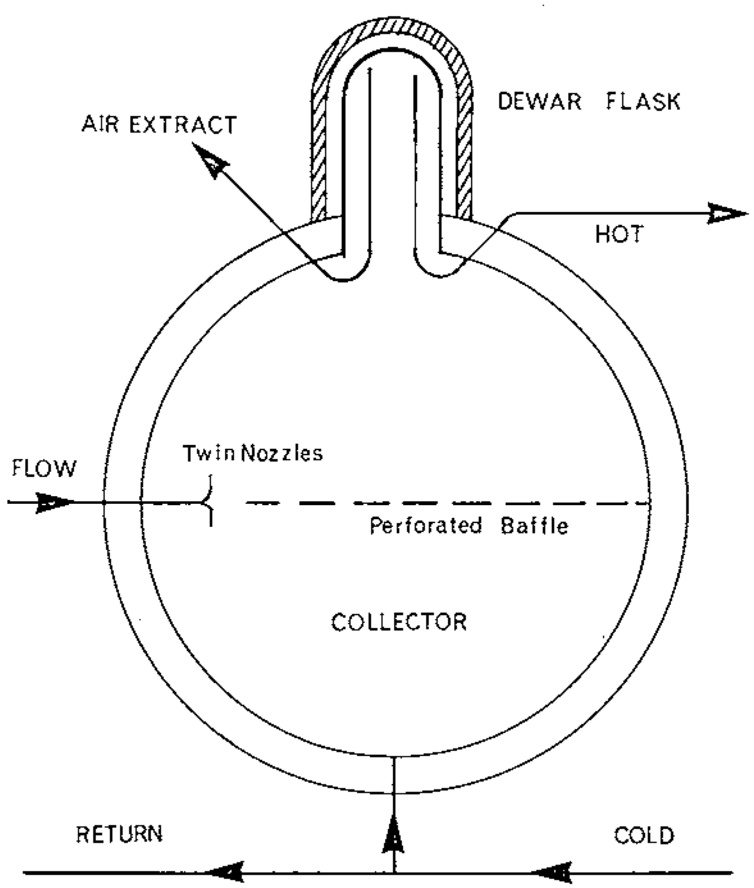


Fig.4 SOLAR STORE

continuous thick overcast it might have to heat 122/35 gall for tub/shower from 46°F to 100°F needing 19/6 units for which a 1 kW heater is enough: with the family at home drawing hot water the store temperature will never fall so low since it is boosted daily. For this low power it is hardly worth installing a boiler. The most economical base booster would be a small heat pump working on the refrigerator cycle with the hot coil at the bottom of the top half or third near one wall above the baffle and the cold coil near the opposite wall at about the same level but below the baffle, so setting up a slow circulation towards the poles. One might hope for a "COP" of at least 2, meaning that 10 units of power would produce the 20 or so units of heat needed, and might do better. As well as supplying half-price heat compared to an immersion heater the heat pump will produce a pool of very cold water at the south pole of the store ready for the boiler to lap up at opening time in the morning and rapidly reheat with near 100% efficiency even on days of low radiation, thus quickly replacing free the heat energy extracted from the lower part of the store by the heat pump during the previous boiler-off period. In Devizes in JON the mean of the worst 3 rises (26) was 5°F over cold feed at 46°F giving a top temperature of 51°F. If a heat pump had reduced the lower two thirds of the store contents to 40°F it is reasonable to suppose that the solar boiler would still reach the same top temperature in prevailing conditions before losses balanced gains; the boiler would have collected twice the heat by using cooled water instead of mains water. The heat pump should not cool the bottom of the store below 40°F since water cooler than this, being lighter, will rise up out of the sump and cool the layers above. In long periods of heavy overcast with night frosts (March 1976) the heat pump may begin to consume its own heat, but this concatenation of climatic circumstances is fortunately rare and in any case half-price heat is being used. A manual override switch may be found necessary to keep the heat pump running all day in such exceptional conditions. A shower household could do with a smaller heat pump but this might not be worthwhile, since the cost would be very little less and the performance falls off with the decreasing size.

The teat needs a peak booster to raise the contents to 120°F if the sun has not. Since it normally receives preheated water at 100°F from store its duty is limited to raising 20/5 gall for tub/shower through 20°F needing 1¼ units for tub. If the electricity is home made (aerogenerator?), a 1 kW immersion heater at the bottom of the teat with integral thermostat will give a recovery time of just over one hour under the worst conditions, normally much less, and on days of high radiation, nil. A shower household could use a kettle size unit of 200–250 watts for the same recovery time. On average the peak booster is only likely to be needed most days in DOJ JON & FLO: on the summer side of MES it will only be needed occasionally, hence the cheaply installed immersion heater though expensive to run is economic in this case (27). If a dewar flask is used, the luxury of constant hot water may continue to be enjoyed with a clear financial conscience. If not, the peak booster should be time-switched to the periods when the household needs hot water.

If compelled to use an indirect system (eg because of an aluminium boiler as at Milton Keynes) the teat should be a separate vessel in the same position and a coil inserted into the top of the store of capacity equal to the teat. This ensures that when a tub/shower is taken, the replacement water fed into the teat is at the top store temperature.

SPACE HEATING

One feels comfortable if one's surroundings are absorbing one's own 40 watts of radiation at a comfortable rate. Overcrowding discomfort is more due to overheated walls and ceiling than to foul air. A hot air blower in a tin shed in winter wind may produce an air temperature of 80°F, yet one will still feel cold because of the cold walls and roof. Double glazing (triple in Sweden) increases comfort by keeping the inner pane warmer. Higher air temperatures than we need in Britain are used in Continental winters partly because the walls are colder. Our so called radiators in fact produce 80% convected heat, so that we light the fire to heat the steel to heat the water to heat the air to heat the ceiling and then the walls and finally our own chilly feet; it seems a long way round!

The best use of the low grade heat from the sun in Britain is in reflecting foil-backed radiant panels covering walls and ceiling. These are true radiators and emit 80% of the heat supplied to them as comfort radiation and do not need a high temperature to do so. A minimum of about 90°F has been quoted as adequate for North America and could be produced by circulating warm water from store in all months except DOJ (27). A tack-on set for an existing house would probably use this system and accept the cost of boosting in DOJ only. The Swedish experimental house uses concrete floors with integral heating pipes carrying water at 25/40°C (77/104°F) directly from their solar store; two such floors heat three storeys.

To get full benefit in Britain a purpose built house would be better. Such a house would have a higher than normal standard of insulation, controlled ventilation, and an interseason heat store to bank summer heat for use next winter. The outer walls should be double cavity, the outer foam filled and reflecting foil lined, the inner carrying warm air heated from store. Unavoidable heat loss from the back of the solar boiler (a very large area) should be used as a heat gain for the house by using the whole area behind as living space and putting the normal attic floor blanket up against the roofing felt under the tiles instead of on the floor. Part of the unavoidable heat loss from the solar store (necessarily large) should be used as a heat gain for the floor of the house, but under tight control to prevent overheating in summer. In such a house, of about the same size as the house in the photo, it should be possible to hold the heat loss to 150 watts/°F or less.

In continental climates with harder winters than ours foundations must be deeper to counter frost-heave. Instead of digging and revetting deep trenches it is normal there to excavate the whole space by machine and use it as a cellar housing the furnace and workshop or playroom. Applied to UK the frost ruled depth would be less but the extra space could be used as a basement pool heat-store by using reservoir/swim pool engineers to convert it economically, balancing excavation costs against retaining wall costs. On some wet UK sites dewatering may be found necessary during construction only, to prevent the empty pool "floating" up out of the ground; the weight of the house should be enough to keep the full pool down. The ground floor area of the house in the photo is about 900 ft^2 and the required pool capacity about 20,000 gallons, calling for a pool depth of about 3 ft perhaps partly above ground but mostly below. The pool should be lagged on all six faces with not less than 1 ft of rockwool or similar material, packed carefully to keep it dry. So lagged it should be possible to keep the heat loss to 200 units a month (32), part of which represents a heat gain to the floor of the house as in the ancient Roman hypocaust. Using a collector slope of 70° or so the temperature difference remains much the same year round, the store water and its surroundings both being hotter in summer cooler in winter. A smaller store could not bank the required amount of heat, since the boiler whatever its size could not produce a high enough temperature (36). The Milton Keynes experimental house using a collector slope of 30° (more efficient in summer) logged 165°F on 26 June 1975, so the top 170°F in Table III seems not unreasonable by September with a steeper slope collector. In any case if the Swedish experimental house can get away with a minimum space heat water temperature of less than 80°F, then in a bad UK year when the top temperature only reaches 150 instead of the designed 170, the minimum will fall from 100 to 80 which may still prove adequate.

A boiler of 27 m^2 sloped at 70° to maximize heat collection during the heating season would in conjunction with such a house and such a heat store maintain a minimum year-round temperature of 100–110°F in an average year (34, 36). Records show that the worst and best years may have sunshine 20% below or above normal so it might be wise to increase the boiler sizing by 20%, to cater for the worst year, to 32 m^2. Without the interseason heatstore, to collect enough heat in DOJ would need 118 m^2—too big to be practical or economic. Accepting boost for DOJ, to be large enough to balance in JON would still need 70 m^2—nearly the size of the back roof of the photo (which is at the wrong slope for JON anyway). Abolishing the dormer windows from the photo house would make 40 m^2 of roof available at about the right slope. A shower household could add the 6 m^2 of boiler area needed for DHW and still be within the available roof area. A tub household unless rationed to 5 in baths, as in wartime, or baths every other day could only add a boiler surface 8 m^2 against 22 m^2 needed for unrationed baths on this particular roof. But a purpose built house could provide the required 54 m^2 at the optimum slope (which depends on latitude) without great modification to the basic house design.

Such a house with such a heat store would need no base booster since the store could never grow cold. A peak booster would be needed for DHW in DOJ JON & FLO only and would be unused the rest of the year which strengthens the argument for the cheaply installed immersion heater for this job. The top store temperature of

170°F is certainly very hot, but not dangerously so; if thought too hot, the pool may be enlarged slightly to bring it down. The Cyprus experimenter (see Table II) had shades ready in case of boiling but they were never needed—losses rise very rapidly with temperature.

A portable boiler would be needed to charge the store when the house was ready. The best time to charge up would be at the beginning of Solar February (6 Feb calendar approx) since the temperature needed then is only 100°F (36) to give the solar boiler the necessary flying start. The penalty for omitting to charge might be a chilly first winter. The building programme should bear this in mind; it would be expensive to finish in September and have to charge to 170°F from 54°F (22).

A tub household using a direct system would pass 122 gall/day through the 20,000 gall store, turning the contents over in 165 days or about six months, which should be enough to keep it sweet. A shower household using only 35 gall/day would take about 570 days or 19 months; since the pool is dark there can be no growth of algae and this period might still be enough to keep it sweet. If an indirect system were essential it might prove necessary to drain down and scrub out every five years, so losing the banked heat and having to recharge.

Depending on relative costs at the time, it might pay to install a heat pump. This could take care of the charging, would enable the boiler size to be reduced to 27 m^2 for the average year from 32 m^2 to deal with a cloudy summer. This would leave 13 m^2 of the photo front roof (windowless) for the tub households' long baths against 22 m^2 needed in a DHW only system: in a combined system with interseason store it might prove to be enough because of the much higher temperature of the "hot" water in summer—hence less needed. The heat pump should be controlled by a slotted cam revolving once a year, the cam profile following the monthly temperatures needed in store (36) and cutting in the pump if the temperature fell more than 5°F below that set by the cam, the other side of the slot cutting out the heat pump when the situation had been restored—no point in doing the sun's work for it.

CIRCULATION CONTROL

With the store below the boiler a pump will be needed, speed controlled by temperatures sensors at the top of the boiler and the bottom of the store generating an AC signal proportional to the temperature difference plus a non-return valve to prevent reverse circulation through the pump (if centrifugal) at night or in cloud robbing heat from store and re-radiating it.

As the boiler warms up in the morning and passes the temperature of the bottom of the store the pump will be started and run at a speed sensitively attuned to the density of the incoming radiation.

On a clear frosty night as the boiler radiates off its remaining heat to the cold stars, the temperature of the contents will fall towards 35°F. Provided the temperature at the bottom of the store has not been allowed to fall below 40°F, the colder but lighter water at 35°F will find its way to the top of the boiler and signal the pump to start (the signal being AC) a slow forward circulation sufficient to prevent ice formation. An override control will be needed to prevent the pump running on a negative temperature difference (boiler cooler than store) occurring at the top sensor outside the range 32–40.

Accuracy and sensitivity are essential in the control system to ensure that all available heat is banked and none lost, particularly that available in the notorious British "bright interval" which is of very frequent occurrence year round. Pump and piping must be sized to ensure no ice is formed even under the worst conditions to be expected in the locality concerned. Vertical waterways in the boiler are to be preferred to ensure quick reaction to frost. Milton Keynes uses anti-freeze, Sweden drains and replaces with nitrogen, Denmark with air, both draining automatically whenever a negative temperature difference occurs: in Britain they would use more energy pumping than they got from our sun!

Generous boiler waterway and flow and return pipe sizing should be used to ease the work of the circulator pump, since the energy needed to run it must logically be deducted from the free energy taken from the sun with its help.

THE GLASS/WATER WALL

From Newcastle (lat 55) northwards, the best winter slope for the collector becomes steeper than 70°. Forced to choose between a flat roof and a vertical wall, the latter becomes preferable—in fact the Danish experimental house actually uses a vertical collector. The climate becomes colder and the radiation carries less energy at the surface because of the longer air path of the rays of the lower sun (about 0·3 units/m²/day in DOJ at latitude 60 against 0·55 in lat 51). Where a boiler of about 50 m² would provide water and space heat in lat 51, we shall need nearer 75 m² in the North—bigger than the present average house roof at the steep slope needed to maximize winter collection.

The required area can most simply be provided by an "A" shaped house, using the whole South face to collect, but using a translucent collector which provides all South facing rooms with a luminated wall admitting ample daylight yet preserving privacy. Doors and windows on the other three sides are conventional.

The South wall is built of structural glass blocks with three cavities, the outer filled with carbon dioxide gas sealed in at the factory to increase the greenhouse effect as used to be thought happened on Venus, the middle with a thin circulating water film plus additives, and the inner with stagnant air to keep the water hot and the room cool in midsummer. The purpose of the water additives is to increase the ability to absorb radiant energy; with a thin film quite a heavy dose can be carried without darkening the room since the whole South wall is luminous by day. They can be tinted to taste, like wallpaper, and will reflect artificial light at night, so making curtains unnecessary.

A basement pool heatstore and double cavity outer walls are used as before. If the additives used are harmless and cheap, a direct DHW system will provide cloudy tinted bathwater which might be rather amusing: otherwise an indirect system must be used with probably periodical loss of banked heat for cleaning.

The glass blocks could be made large enough to be worth emplacing by crane and might have two male spigots on top mating with two female below, conical in section with jointing washers ready fixed, in order to carry the circulating water.

The photo house is about 10 m wide by 7 m high to the ridge. Redesigned as a leaning "A"—the lean depending on latitude—the South wall from DPC to ridge sloped at, say, 80° would just about provide the 75 m² or so needed in the North.

FINANCIAL

Fig 5 shows the rise in the cost of the cheapest alternative domestic fuel over the years 1970–76; in 1970 it was oil, in 1976 gravity-fed anthracite grains: one cannot predict what it may be by 1982, but can safely say that it is very unlikely to cost less than 0·8p/useful kWh which makes the solar boiler output (34) worth £77.70 (37) for 27 m² in lat 51, or £215 for 75 m² in lat 60.

Table VI shows how an initial fuel saving of £100 pa would make an investment of £1500 to save it worthwhile if you were content with a payback period of just under fourteen years, assuming a mortgage rate of 7% net of tax relief, and an inflation rate of 8%. House mortgages normally run for twenty-five years, and collectors have been working in Arizona for more than forty years. It has been assumed that fuel prices increase no faster than other prices, but it is more likely they will increase faster as they become scarcer.

The government could encourage this form of energy saving best by providing a top-up mortgage on top of the standard house mortgage for owners willing to build an approved solar heat design at extra first cost but much lower running cost—the latter providing the extra margin to cover the extra repayments.

Gross Costs

A current panel on the market recommended by CTT (G) costs £45 for 0·93m² excl VAT, carriage and glass, so a solar boiler of 33 m² sufficient for showers and space heat in an average year in lat 51 would today (1976) cost £1,600. As demand increases under pressure of fast rising fuel costs, and intensive R&D starts to pay dividends, this might come down to perhaps £400.

The basement pool heatstore would possibly cost £2,000, the double cavity outer wall £1,000, plumbing and controls £500. The glass/water wall in quantity production might cost £2,000 for 75 m².

Savings

The unglazed roof panels would be connected together to form an array to suit the roof available, then covered with continuous patent glazing bars and glass, thus

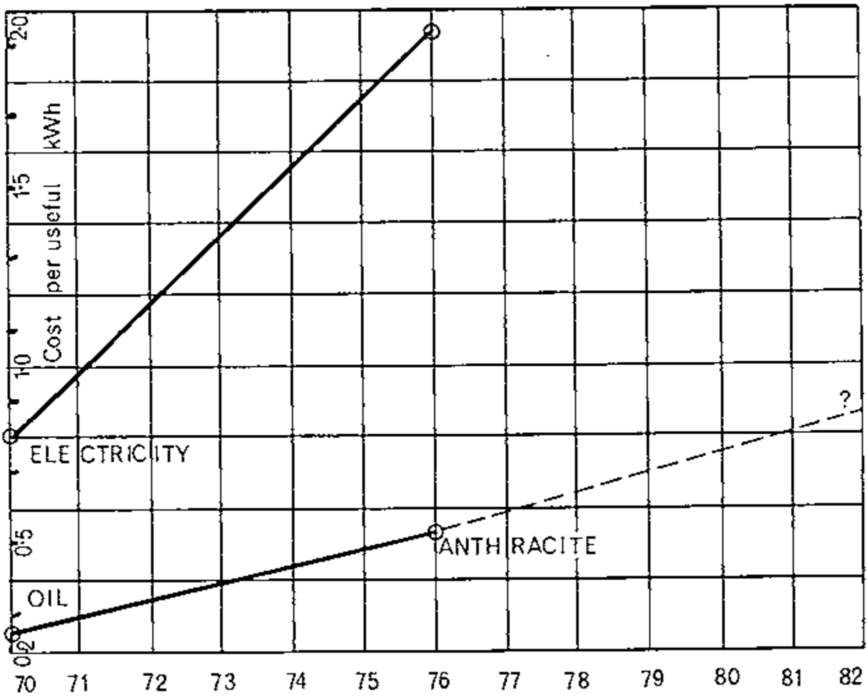


Fig 5 FUEL PRICE

TABLE VI—LOAN REPAYMENT BY FUEL SAVINGS

Year	*Loan*	*Interest*	*Fuel Saved*	*Repayment*
0	1500	105	100	−5
1	1505	106	108	2
2	1503	105	117	12
3	1491	104	126	22
4	1469	102	136	34
5	1435	100	147	47
6	1388	97	160	63
7	1325	92	173	81
8	1244	86	186	100
9	1144	79	200	121
10	1023	72	215	143
11	880	62	232	170
12	710	50	250	200
13	510	36	270	244
14	266	19	290	266 (£5 over)

forming the roof of the house and saving the cost of conventional roofing, perhaps £430 for 33m².

The basement pool heatstore saves the cost of digging foundation trenches, filling with concrete and engineering brick, and laying floor slab with DPC & DPM, say £1,500. The double cavity outer wall replaces the single cavity conventional wall costing perhaps £650.

Plumbing and controls are similar to those needed for a conventional boiler and circulator system for radiators and DHW less the cost of boiler, fuel store, flues etc, say £250.

The glass/water wall replaces a single cavity brick wall of equal area 75 m² costing perhaps £500, and saves the cost of windows, lintels, wallpaper and curtains say £250.

Net Costs

Lat 51, Showers and Space Heat			
	Boiler	£1,600–£430	1,170
	Heat Store	£2,000–£1,500	500
	Double cavity wall	£1,000–£650	350
			£2,020
	Less boiler, fuel store, flues etc		250
			£1,770
Lat 60, Tub and Space Heat, Glass/Water Wall			
	Collector	£2,000–£750	1,250
	Heat Store & double cavity walls		850
			£2,110
	Less boiler, fuel store, flues etc		250
			£1,860

The writer is not currently in close touch with the building trade, and these costs would need accurate updating before any firm conclusions are drawn. However, the indications are that a further small increase in fuel costs ahead of building and other costs will very soon make solar heat an economic proposition. An investment of £1,770 in lat 51 would pay back in under fifteen years and of £1,860 in lat 60 in less because of the higher fuel savings.

COLLECTOR ORIENTATION

Hodges (H), by feeding actual weather records to a computer, has come up with the following answers, lat 51 presumed:—

For max annual collection: optimum bearing 174°, slope 32°
For December–January max: bearing 178°, slope 65°

Comparing measured results for London & Devizes (Table II)

Place	*Object*	*Bearing*	*Slope*	*Collection*	
				Annual	*Heating Season*
London	Research	180°	40°	0·73	20%
Devizes	Winter heat	187°	70°	0.69	30%

Although London collected more heat in the year than Devizes, 80% of it fell outside the heating season. Devizes collected 50% more heat than London during the heating season when it could be used directly without storage.

The writer can think of nothing but swimming pools which need heating in summer. For every other known application, winter heat is what is needed. In Britain this is best collected by a steep slope (steep pitched roof) of at least 60° to the horizontal in the Channel Islands (lat 49) increasing to at least 72° in the Shetlands (lat 61).

The current commonest roof pitch of about 30° will collect more heat in the year, but would need a huge interseason store reaching dangerously high temperatures (with consequent high losses or very expensive lagging) if it is to be banked for release next winter.

The Swedish experimental house at Malmo (lat 55, same as Newcastle) "The solar collector bank is inclined at an angle of 70° which gives the highest solar energy gain during the heating season, with respect not only to beam radiation, but also to diffuse and reflected radiation" (N).

Optimum bearing remains to be proved: meanwhile 180° is probably not far wrong.

CONCLUSION

A plea is made to close the chapter in the book of technology which works in terms of cheap and abundant fuel, high temperatures, powerful pumps, narrow pipes, and poor insulation. For the future of our children we must start now to think in terms of doing the best we can with what Nature has given us—second nature to a Sapper—and trying to achieve a harmonious and elegant solution by first ditching all preconceived notions, and instead bringing a trained intelligence to bear.

"The variety of errors to which meteorological observations are liable when made with doubtful instruments by pioneer enthusiasts in questionable exposures is terrifyingly large" (J).

Notes

A *Oxford Advanced Atlas*—Bartholomew
B *RE Journal*, June 55—"Water Heating for Domestic Purposes in the Tropics"
C *RE Journal*, March 56—"Solar Heating for Married Quarters"
D Results reproduced by kind permission of the experimenter
E *Journal of the Institute of Fuel*, July 54—"Solar Energy for Domestic Water and Space Heating"
F *The Complete Book of Garden Magic*—Biles—Jenkins
G Conservation Tools & Technology Ltd, 143 Maple Road, Surbiton Surrey,
H "Using solar energy in Housing"—Hodges—*RIBA Journal*, Apr 73
I International Solar Energy Society (UK Section), 21 Albemarle Street, London W1
J *Climate and the British Scene*—Manley—Collins
K The author wishes gratefully to acknowledge much help received from the old RE Works Service (now no more) with the installation, and from the Physics Department of the RMCS Shrivenham with the instrumentation and with interpretation of results, eg why no ice?, also, of course, the Met Office.
L Any reader having questions is asked to supply a big SAE and a little patience!
M Solar Trade Association, 88 The Avenue, London NW6 7NN
N Conference on European Solar Houses Apr 76, organized by ISES see I above

Ritten Kwik Kwiz—2

1 Write down the numbers from one to ten. (Marks will be deducted for every number out of sequence).

2 Name the winning jockey of the 1976 Greyhound Derby.

3 Explain Einsteins Theory of Hydrodynamics or write your name in block letters.

4 Who invented Stevenson's Rocket?

Cyprus Demarcation Task

LIEUT-COLONEL T A LINLEY, RE, MA, ARICS

CYPRUS was headline news for two months in the summer of 1974 (and it has never been far from the front page since). On 15 July there was a National Guard coup against the government of President Makarios and on 20 July the Turkish Armed Forces intervened in Cyprus. Peace talks were held in Geneva and they resulted in a cease fire agreement. The Geneva Declaration of 30 July authorized the formation of a Committee and gave it the task of establishing the limit of the areas occupied by the Turkish Armed Forces at the time of the cease fire—2200 hours local on 30 July 1974.

The Committee was formed in Cyprus and consisted of Colonel J J G Hunter, British Representative and Chairman, the Defence Adviser at the British High Commission, Nicosia; Colonel C E Beattie CD, UNFICYP Representative; Colonel Nezihi Cakar, Turkish Representative; and Major E G Tsolakis, Greek Representative. In attendance were Lieut-Colonel T A Linley RE, of Survey Directorate Near East who was accepted by the Committee as an impartial survey and mapping expert and Major R K Collins of HQ BFNE as Secretary. A survey cell, manned by members of 1 Air Survey Liaison Section RE from Episkopi was formed. This was commanded by WOII R Jones RE, and located adjacent to the Committee Conference Room in order to give direct survey and mapping support to the Committee. It was also arranged for additional cartographic and printing support to be provided by the Department of Lands and Surveys, located in Nicosia, should it be required. Mr A Christofi of the Department was as helpful as ever.

The Committee met for the first time at 1615 hours local time on 2 August 1974 at HQ UNFICYP Nicosia. After a brief opening ceremony Colonel Cakar and Major Tsolakis produced their own 1:50 000 scale maps marked to show their views of the limit of the areas occupied by the Turkish Armed Forces at the time of the cease fire. Their views differed considerably! So did the maps on which they were marked. It was then agreed that British Military Survey maps were the best ones available and should be the working maps of the Committee. The relevant information was then transferred to these maps. During Committee discussions it rapidly became clear that it was impossible to agree on the limit of the areas occupied by the Turkish Armed Forces at the time of the cease fire as there had been subsequent movement. It was accepted that the best the Committee could achieve was to establish the limit of the areas occupied, on the day of a Committee visit to those areas.

Visits by the Committee to the Turkish forward areas started on an afternoon of 4 August. Movement on the first two days was by a *PUMA* helicopter of 33 Sqn RAF which was generously decorated with Union Jacks including a very large one slung underneath. This was fully retractable, suitably weighted and if the engineering was not to an approved design, it did make recognition by the opposing forces that much more certain. The *PUMA* was fitted with an intercom system that enabled Committee members to have discussions whilst airborne over the front lines. On 4 and 5 August most of the eastern and western sides of the Turkish enclave were visited. Lieut-Colonel Linley recorded the line portraying the limit of the occupied areas by occasionally having the helicopter land in the Turkish forward positions but generally from airborne observation and map plotting. The agreement of Colonel Cakar and Major Tsolakis to the map position of all the helicopter landing points and their provisional agreement to the remainder of the line, was obtained on location. After each days work the line was neatly drawn on maps, so that each Committee member could discuss it with his superiors, before the first meeting the following day, when the previous days work was confirmed.

On the morning of 7 August, Major Tsolakis agreed that the Committee could start working in the Nicosia sector before the completion of the work in the North West of the Turkish enclave where the Turkish authorities were forbidding access to

Photo 1. Committee at work near Nicosia Airport.

their forward areas. The line in the Nicosia sector was completed on 7 and 8 August with the Committee moving by helicopter, tracked and wheeled vehicles and on foot within the Old City. In the Old City, while demarcating the Turkish forward positions an exchange of fire between the opposing forces led the Committee to get off the streets and have an impromptu conference in a local bar, where rapid progress was made! The method of work, using progressive confirmation was the same as on 4 and 5 August. There were a few small areas where both a Greek and a Turkish

Photo 2. Committee at work in Nicosia on the Green Line.

Cyprus Demarcation Task 1 & 2

Photo 3. Committee members signing the final agreement. *L to R:* Major E G Tsolakis (Greece), Colonel C E Beattie (UN), Colonel Nezihi Cakar (Turkey), Colonel J J G Hunter (UK).

view of the limit of the Turkish occupied areas had to be plotted, due to a difference of opinion of the meaning of the word "occupied". Considerable care was taken in positioning the line with reference to the Chairman's house, where some of his best suits were found to be bullet marked—fortunately whilst in the wardrobe.

On 8 August Colonel Cakar requested that the southern end of the eastern side of the Turkish enclave, which had been surveyed on 5 August, should be revisited. This the Committee did by helicopter and found in some places that the Turkish Armed Forces were forward of the positions recorded on 5 August. The new line was plotted on the map and agreed by Colonel Cakar and Major Tsolakis. Colonel Cakar continued to refuse the Committee access to the Turkish forward positions in the North West of the Turkish enclave. This was the only Turkish forward area not visited by the Committee so that the field work was now complete. However Colonel Cakar and Major Tsolakis informed the Committee where they considered the lines should be, and both lines were recorded on the map. The final lines were drawn on the British Military Survey maps at the following scales:— 1:2500 for the Old City of Nicosia; 1:7500 for the Nicosia sector and 1:50 000 for the remainder of the area. Each Committee member was given a copy of the set of maps on the evening of 8 August so that he could discuss it with his superiors.

As a result of overnight discussions a few minor changes to map lines were agreed by the Committee, an Agreement was signed, and final sets of maps were then produced. On completion of the maps at 1400 hours local time on 9 August 1974, the Committee Chairman flew by *PUMA* and *CANBERRA* via RAF Akrotiri to Geneva, in order to brief the Chairman of the reconvened Geneva Conference and so complete the Demarcation Task.

As is well known, the cease fire agreement reached at Geneva broke down very shortly afterwards when the Turkish forces made a further advance.

* * *

Hanggliding

BY LIEUTENANT J F CROMPTON, RE

HANGGLIDING is not, as most people imagine, a new idea. All of the original pioneers of flight flew what were in effect hanggliders. They ran off hills with their machines tied to them in various ways, and most of them, including such people as Lilienthal, eventually killed themselves! However with the advent of true powered flight it became obvious that man's legs were not the best sort of take off and landing gear, and so the pilot was more or less enclosed inside his machine and wheels or skids were used.

It was therefore natural that, when gliding developed as a sport, gliders should be fitted with wheels or skids (there was also the fact that gliders by this stage weighed too much to be easily carried anyway!), and it required a completely new line of thought to bring us back to hanggliding.

In the sixties NASA were experimenting with various ways of bringing a space capsule, manned or unmanned, back to earth; and amongst the team working on this project was Dr Rogallo. He produced a design, known as the Rogallo Wing, for a steerable re-entry parachute. The wing was triangular in plan and was to have been guided back to earth by a homing signal which would have caused the capsule to shift its weight beneath the wing and thus steer itself towards the signal source. NASA spent several million dollars on this and then decided that it was not what they wanted.

However the breakthrough had been made. There was now what was effectively a new design of flying machine, and one moreover which was light and could be comparatively easily built. "Easily" is not really the word for it. The first sport Rogallos were constructed using bamboo, polythene, and bailing twine! And the concept of the design was new. Effectively it was a single surface with no movable control panels and no tail surface, and it would seem impossible to achieve that inherent pitch stability which a conventional aircraft achieves by placing the centre of gravity ahead of the centre of lift and compensating for this using the tail surfaces which provide the horizontal stabilization. However by using what is known as keel reflex—an upward bend towards the rear of the central fore and aft spar—the lift at the rear of the kite is effectively lessened, and at high speeds totally destroyed, thus giving the required counter moment.

Another factor which increases the safety of the Rogallo as opposed to conventional aircraft is the pendulum force which exists between the pilot and the kite itself. The kite tries to fly and the pilot tries to fall under gravity and this in itself produces a turning moment which leads to pitch stability.

But what of roll stability? Obviously the pendulum effect will tend to lead to stability but the Rogallo has one other great advantage. Because of the way the sail is cut and the shape it adopts in flight it presents a varying angle of attack from the centre to the wingtip. In normal flight the centre of each wing panel is providing most of the lift whilst the inboard part is presenting almost too high an angle of attack, and the outboard part too low an angle. This leads to good stability but the effect is even more marked as a stall is approached, as the effective lift producing portion of the wing moves outward. At the stall the wing extremities are flying, and even if the pilot takes no correcting action the kite, if properly trimmed, will drop its nose and resume stable flight. Thus we have a machine which is inherently stable about both major axes and which when properly produced is almost fail safe.

To control the kite is simplicity itself. The pilot sits in a harness behind a delta frame hanging from the centre of the kite. When he pushes the bar of the frame away, he causes a weight shift to the rear. This decreases the angle of attack and causes a levelling off and a decrease in speed. When he pulls the bar towards him the weight shift forward causes a dive and an increase in speed. A shift to the side causes the wing to drop on that side and hence the kite turns in that direction.

Photo 1. The Delta Frame.

The technique of flying on a hill is very similar to ridge soaring in a conventional glider. Providing the air moving towards and over the hill attains a vertical component greater than the sink of rate of the kite, the kite will take off and go upwards, and providing it maintains its position in the lift band (usually by tacking backward and forward across the face of the hill) it will stay up until the wind drops. So much for the theory, now for the practice!

I first met a hangglider on a bleak Yorkshire hill. The glider had been purchased by 48 Field Squadron which I had just joined, and several people had already been initiated into the joys of pure flight. The score at that stage was one chipped spine, one broken wrist, several sprained ankles, and many many bruises. I was being taught by one of the experts who had had proper instruction from a hanggliding school and as I had never seen one flying before it did not increase my confidence to see him run down the 75 ft hill carrying the kite and shouting "It will fly, don't worry" three times in succession. When he suggested that it was probably because he was too heavy for the kite in that wind (almost nil at that time) and that as a light-weight I should have no trouble and should try it, I thought he was mad. Five minutes later, strapped into the harness and running, I *knew* I was mad, but then the amazing moment occurred—*I flew*. The kite lifted me gently off the ground, flew down the hill and deposited me on my feet at the bottom; as easy and as simple as could be. The sensation was amazing—to have been flying 50 ft above the ground and still to be intact at the end. The feeling of freedom during the flight and, above all, the knowledge that it was all my own work (no engine, no tow, just my own two feet and the wind) were quite exhilarating.

After a further two flights (they seemed endless but were probably not more than twenty seconds) I was forced to give up out of sheer exhaustion; running up hills with a kite in order to fly quickly down again is the quickest route to physical exhaustion I have found yet, and flying when you know very little of the theory and are trying to do it by trial and error is mentally very exhausting. I was certain of one thing—this was a sport well worth pursuing.

Equipped with two more hanggliders which the Regiment obtained from the Nuffield Trust, it became apparent that if we wished to have a successful club we really needed to be properly instructed, and so we went to Brighton. Brighton is one of the best flying areas in the UK, and within a ten mile radius there are sites for

Photo 2. Taking off in the Aberdares (Kenya) at 10,000 ft.

Hanggliding (2)

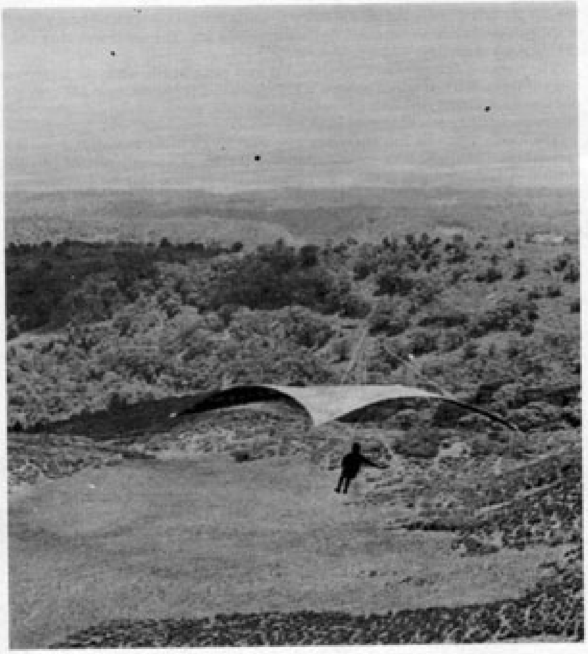


Photo 3. Above the Aberdares.

flying in just about any wind direction. It is therefore hardly surprising that it has a large population of hanggliders, and I was amazed to see so many kites in one place at one time. Within a week all four of us who had gone down had passed the "jump and hope" stage and were well into soaring techniques. And soaring is where the flying really becomes interesting. If done properly it means that the kite does not have to be carried up the hill, and this is a tremendous incentive in itself!

Filled with enthusiasm we set off back to Yorkshire determined to find bigger and better ridges on which to improve our flying. However we soon ran into a familiar problem. It is very hard to find sites with both a take-off and landing zone; and if you do find one, the landowner usually seems to be anti-flying! With only around three thousand people flying in UK at the moment you would think that it would be easy to find a new site on which one could fly in peace and quiet, but this is just not so. The three thousand have managed to ferret out just about every suitable hill over fifty feet in the country.

We therefore looked forward to our Squadron exercise in Cyprus. The Island had never been flown before, and a study of the maps showed several promising areas. We found an almost perfect site only a few miles down the road from Akrotiri at the ancient ruins of Curium. A café with patio overlooks a 300 foot hill with a cliff to

Hanggliding (3)

the left providing really big lift for soaring, and a 300 yard stretch of bare ground at the bottom, before another café on the edge of the sea. The sea breeze blew onto the hill every single day.

The National Hanggliding Championship took place in UK while the Squadron was out there. We had hoped to enter a full regimental team, but we could only get one man back in time, so Lance Corporal Trickey (who has since been commissioned) represented 38 Engineer Regiment as an individual.

The flights which we had in Cyprus will always stick in my memory—forty-five minutes spent hanging above the cliffs watching the sun sink slowly into the sea on a beautifully warm evening is only one example. It was there that we executed our first 360 degree turns. This sounds simple, but the one time hanggliders are really dangerous is when the wind is behind them. However all good things have to end sooner or later and this applies expecially to overseas tours. We were soon back on the crowded UK hills with really only one thing to look forward to—a forthcoming five month tour in Kenya. And in Kenya the flying is really tremendous. There are some three thousand foot high ridges where the lift is so strong that if you throw a rope down it will come back up again. Allied to this are the thermals which are up to three or four times as strong as those in UK, and provide some really interesting flying. Unfortunately the wind was in the East for most of the tour but some of us are determined to return when the Westerlies arrive and attempt to fly the length of the Rift Valley: a project which is assuming something of the status of the Everest of Hanggliding.

Correspondence

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THE REPAIR OF DAMAGED BUILDINGS

Sir,—I have read with interest the article by Mr Peter S Rhodes in the March issue of the *Journal*, but wish to comment on his remarks about "dry rot".

It is important to realize that there are many types of rot which attack timber in buildings, but the most important are the following:—

(1) *Merulius lachrymans* (true dry rot).
(2) *Coniophora cerebella* (wet rot).
(3) *Poria* species (*P Xantha—P Vaillantii*)

Of the above, *Merulius* is the most important, in that it is the most virulent and can spread its infection over very long distances by means of strands which penetrate mortar joints and even, in some cases, porous brick or stone. It can be recognized by the soft white cushions of mycelium on the surface of affected members (in certain conditions this can be silver grey with yellow and/or lilac tinges). If fruiting bodies are present the spores are of a rusty red colour. The effect on timber is to reduce it to a light brown colour, with the grain reduced to a cubical form with deep cracks across the grain. The wood crumbles readily under the fingers. *Merulius lachrymans* can only exist in a fairly narrow range of conditions, namely at temperatures not exceeding about 26°C and at moisture content of not less than 20% or more than about 40%. It is most active under ill ventilated conditions with high humidity.

Coniophora cerebella, on the other hand, requires a high moisture content of 40/60% to flourish and unlike *Merulius* ceases activity on drying of wood. This fungus may be recognized by the sparse dark brown/black strands of mycelium and the inconspicuous olive green/olive brown skin of the fruiting bodies. The effect on wood is similar to that of *Merulius*, except that the damaged wood is of a darker colour and the cracks across the grain are not so obvious on the surface.

Fungus of the *Poria* species caused the wood to turn brown with a cubical formation which is less pronounced than with *Merulius*. It may be recognized by the pure white or yellowish white mycelium with sometimes small or sometimes large strands. The maximum temperature for growth is about 36° and it requires moister conditions than does *Merulius*.

So far as treatment is concerned, whilst creosote is effective it is unsatisfactory in as much as it is not possible to paint over it. It is more satisfactory to treat all surfaces liberally with an organic solvent type of preservative of which there are several excellent brands. (*BS Code of Practice 1282/75* is a guide to the choice and use of perservative).

It is important to realize that ready treated timber for replacement purposes is normally available as also is reliable specialist treatment for affected buildings.—Yours faithfully, S M Hollway.

The author comments:

"I am most grateful to Colonel Hollway for adding the detailed notes about timber rot. Editorial restriction on space encouraged me to write a very brief and summarized set of notes and I am now delighted to see that more space is available for what to me is a fascinating and important subject."—PSR

Major-General Sir Robert W Ewbank KBE CB DSO MA
Rustington
West Sussex

MEETINGS WITH MONTY

Sir,—I much enjoyed Mark's "Meetings with Monty." My own several encounters were on more peaceful occasions. The first was when Monty visited the Tyne-Tees (TT) bridges which we (50 Div Sappers) were building over R Rhine at *REES*—I believe the longest military bridges built in any war or any peace! Monty insisted on walking across one bridge. When I told him it was a mile long, he relented and drove across.

My wife first met Monty at a dinner party at the C-in-C's home (General Sir Dudley Ward) in Germany. When I introduced her to the Great Man, he asked, "Have you met me before?"!! She immediately replied, "No—but you served under my father in World War One!" (Score 15–15). This started an animated conversation about "Pontoon Forster", whom—the Field Marshal said—he had admired so much (Brigadier David Forster, CB, CMG, DSO—a Sapper—was GSO 1 of a division in France; Monty his GSO 2; and the man who eventually became Monty's head Padre—and later Chaplain-General—the GSO 3). It may encourage Mark to know that Monty, the Infantryman, served under a Sapper!—Yours faithfully, R W Ewbank.

Brigadier Sir Mark Henniker Bt CBE DSO MC DL
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ROLLERS

Sir—Long years in the Corps led me to believe that I had learnt all there was to learn about rollers for moving heavy weights; but now I am not so sure.

Doubt dawned in an odd way. I was helping one of the men who works in my business to move an empty oil tank across the Warehouse, and naturally we used rollers. The tank moved easily; but when we had finished and I picked up the rollers I noticed that one of them was not round. It was an odd shape, and I sought to find out its geometry. How could any shape but one whose cross-section was circular be any good as a roller?

If you look at Fig I you will see a weight, W1, mounted on conventional circular rollers, and in Fig II a similar weight, W2, on elliptical ones. One knows by experience that W1 will move more easily than W2; and reason soon tells one why. The reason is that whereas the circular rollers have a constant width, so that W1 remains the same height above the floor all the time, the rollers under W2 have a varying width, so that W2 has to be made to rise and fall as it travels. If therefore, you could find some curve, other than a circle, that has a constant width it would apparently fulfil the function of a roller equally well. Such, at least, is the theory.

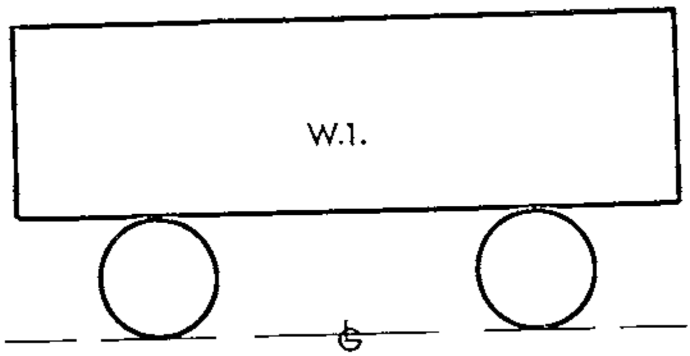

Fig I. W.1. on Round Rollers

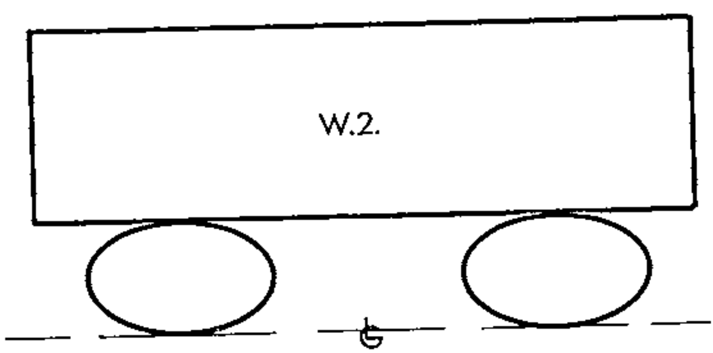

Fig II. W.2. on Elliptical Rollers

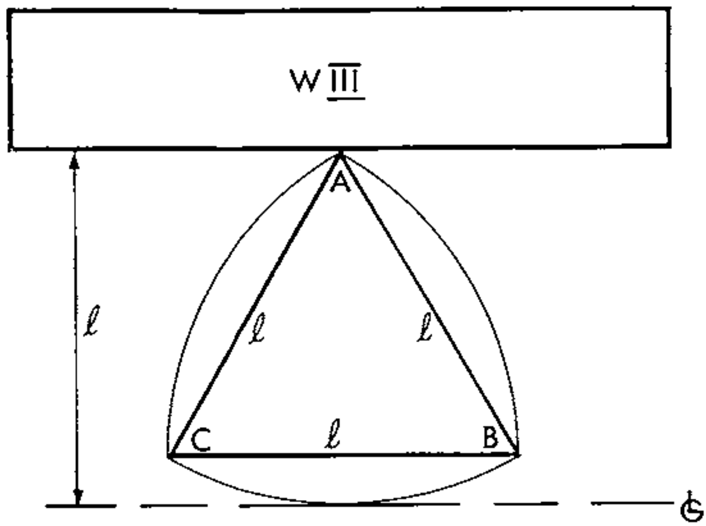

Fig III. Curve of Constant Width = ℓ

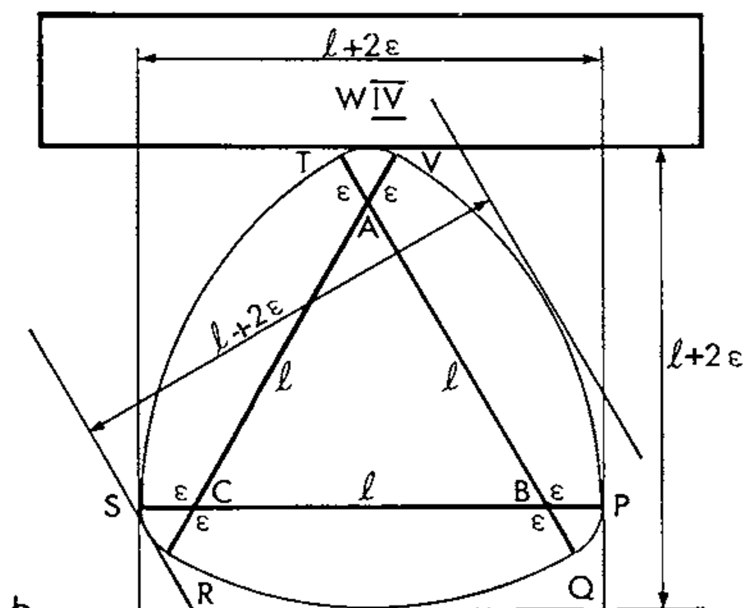

Fig IV. Curve of Constant Width = $\ell + 2\varepsilon$

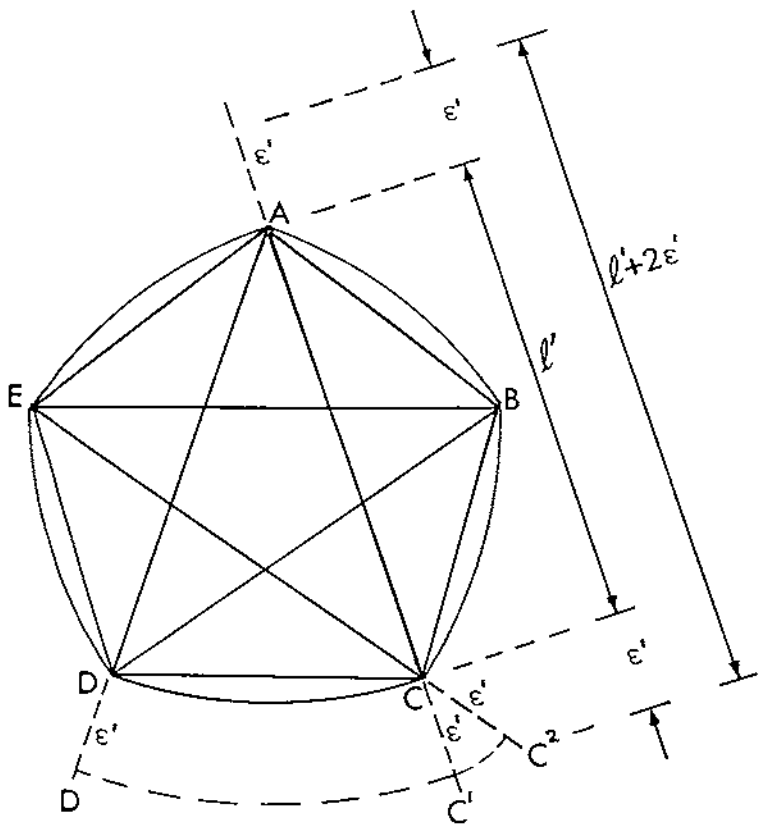

Fig V. Curve of Constant Width based on a Regular Pentegon

It occurred to me that the way to begin my research was to take some regular polygons and mess about with them. I accordingly began with an equilateral triangle, a square and a regular pentagon. The square very soon eliminated itself, because all my efforts to tidy it up merely tended to make it a circle. But the other two figures offered interesting possibilities.

Look at Fig III. Here we have an equilateral triangle ABC with sides = l. With centres A, B, C, in turn, and radius l draw the three arcs BC, CA, AB; and there you have a curve of constant width—a width always = l. So if, as in Fig III, you mount W III on top of it you will not have to raise and lower it as you push it along. The roller of this shape, based on a triangle, is apparently adequate. But the corners offer practical difficulties—slipping and so on and have to be "rounded off".

Suppose you extend each side of the triangle by a short extension = ϵ in both directions, as in Fig IV; you can then draw the arcs shown in the following table:—

Centre	Radius	Arc		Radius	Arc
A	$l+\epsilon$	QR	and	ϵ	TV
B	$l+\epsilon$	ST	and	ϵ	PQ
C	$l+\epsilon$	VP	and	ϵ	RS

In this manner you get quite a "comfortable" roller to put under W IV. As you push W IV along it never rises, but remains constantly at a height $l + 2\epsilon$ above the floor. What is wrong with that? Nothing that I can see. Now try with a regular pentagon.

Look at Fig V. One knows intuitively, and could perhaps have been able to prove geometrically some fifty years ago that the five triangles ACD, BDE, CEA, DAB, and EBC are identical isosceles triangles, each with two equal sides of length l'. It is, therefore, possible to draw the arcs shown in the following table:—

Centre	Radius	Arc
A	l'	CD
B	l'	DE
C	l'	EA
D	l'	AB
E	l'	BC

The result is another "comfortable" curve, but not a circle. It can also be improved in the same manner as we improved the curve based on a triangle. Each side must be extended in both directions by an extension = ϵ' and then we can draw the arcs as indicated in Fig V by dotted lines. The constant width remains at $l' + 2\epsilon'$ as it revolves.

None of these shapes will act as a wheel, because there is no suitable "centre" for an axle. They would also be rather difficult to make; but all seem as good as a circular roller.

Fumbling in this way, I came to a general conclusion, namely: Any regular polygon with an *odd* number of sides can easily be converted into a curve of constant width, other than a circle; whereas no regular polygon with an even number of sides can be converted into any curve of constant width except a circle. When, however, the odd number of sides becomes large, the finished article tends to become circular until, when the number of sides is infinite, it *is* circular. Perhaps this is part of the *Magic of a Circle*.

Nothing in the above makes any claim to originality. Long ago Aristotle wrote: *It is not once nor twice, but times without number, that the same ideas make their appearance in the world.* Euclid very likely set it all out properly 300 years or so BC. But it does seem to me odd—and I write as a former CIF at Chatham—that this curious phenomenon was not widely known in the Field-works School. It is just the sort of thing that would have appealed to the more academic types there. Not that I was ever one of them!

However, perhaps there is a catch in it somewhere: but where? Can any reader elucidate it?—Yours in perplexity, M C A Henniker.

* * *

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BRIGADIER J H D BENNETT CBE

Sir,—The Obituary Notice of Brigadier J H D Bennett in the March issue makes no mention of his voluntary service to the Corps after his retirement.

From 1957 to 1965 he was Honorary Treasurer of the RE Association, and as Chairman during most of that period I would like to pay a tribute to his very valuable services to the Association. Not only was he a wise Treasurer, but he was a tower of strength in dealing with the many problems which the Association had to face.

As Chief Engineer Eastern Command from 1951–53 he was an "ex-officio" member of the RE Benevolent Fund Committee. On retirement he was elected an unofficial member, and he served until the two Associations amalgamated in 1968. I cannot speak personally of his work with the RE Benevolent Fund, but the link which he and Brigadier E C R Stileman provided between the two Associations was of great value to the benevolent work of the REA.—Yours faithfully, A J H Dove.

Memoirs

BRIGADIER A E WHITE

Born 28 February 1895, died 17 November 1975, aged 80

AUBREY EDWARD WHITE was commissioned in the Royal Engineers in February 1915. The son of Edward White, a Lincoln solicitor, he was educated at Charterhouse where he displayed well above average scholastic ability in his achievement of both junior and senior scholarships and an open scholarship to Pembroke College Cambridge. After wartime courses at the "Shop" and the SME, he was selected for the RE Signal Service, in which he spent a full three years on the Western Front in signal units of the 5th Army, notably in 15th and 19th Divisional Signal Companies.

In June 1920 he joined No 4 Supplementary Class at the SME, which consisted largely of subalterns completing their Regular training, in most cases after varying periods of exacting war service. Life was to be enjoyed to the full in sport and all forms of subaltern gaiety outside classroom and workshop. "AE", as he then began to be known to distinguish him from the late C C S White who was on the same course, was slightly older than the course average. He must have exerted something of a steadying influence on this high spirited class, for as one ex-member writes "though on good terms with everyone he gave the impression of watching with benevolent amusement the antics of us lesser mortals, perhaps still not quite grown up!" In an age when appearances counted for a great deal, he was well known for his impeccable appearance, whether in uniform or plain clothes. As a YO, being rather a "loner" by nature he was not a great team games player but he was a keen and accomplished golfer and a good shot.

In February 1922 after posting to India, he joined a proud and distinguished group of sappers in Roorkee, in the KGV'sO Bengal Sappers and Miners. "AE" must have particularly enjoyed his first Indian tour, Commanding the Bengal Sappers 35th Field Troop which as a small independent mounted unit was a singularly colourful and coveted Captains Command. He soon became a good horseman and excelled in the polo field and in occasional racing in the pleasant surroundings of Roorkee and in the Cavalry Brigade at Risalpur. A contemporary Bengal Sapper writes: "he had the courage to be independent when he wanted, for example when he committed the almost unforgivable error of marrying whilst a junior officer". He had applied for leave to go to the hills and it was assumed that he was going, as convention approved, on a shooting trip. When on his return, he went into the

Adjutants office to "sign the book" he met the Commandant who asked "Hello, White what did you get?" and "AE" replied "I got engaged." The thunder, as the Commandant slammed the door reverberated all over Roorkee. Nevertheless his marriage to Suzanne Yvaroski in 1923 proved to be a devotedly happy and fulfilled one. They returned home in 1927 for service in works appointments at Blackdown and Didcot, which was followed by two years as OC 55 Field Company at Catterick in 1931–33. This was evidently another full and rewarding tour, during which he developed a particular passion for fishing, which as with many fishermen, stayed with him for the rest of his life. After a second five year tour in India this time in Works and notably as GE Bareilly, he began in 1938 a four year association with London District first as CRE and then in 1940 as Chief Engineer for the worst months of the London Blitz.

In August 1943 he became Chief Engineer (Works) in 21st Army Group which was followed in 1945 by his final appointment as Chief Engineer in Persia and Iraq.

Meanwhile the illness from which Suzanne had suffered for some years had steadily become worse and he decided to retire to live in surroundings which would improve her chances of recovery. So after retirement in 1946 they went to live in

Brigadier A E White

Switzerland, initially in Montreux where for a while the Swiss climate helped Suzanne and they were able to lead the continental way of life which they both enjoyed, including excellent fishing. However, to his great sorrow she died in Pau (France) in 1950.

"AE" then continued to live in France and in 1962 he married Mme Solange Maneuvrier who shared his particular love of this part of the country. He died at his home in Bidart (Pyr Atlantiques) in November 1975.

"AE" was very much an officer of his time; cultured, able and high principled. By no means gregarious by nature, he formed deep individual friendships and was devoted to his family. Our sincere sympathy goes to Solange and to his son John who is Professor of the History of Art at University College London.

DJNG

BRIGADIER L F HEARD, CBE

Born 30 October 1903, died 8 April 1976, at age of 73

LEONARD FERGUSON HEARD was born at Magilligan, Co Londonderry. From early days Ted had what was known as a weak stomach, because of this throughout his adult life he was inclined to be over-careful of himself. Nevertheless he took pride in providing the very best at his table and took pains to study the individual tastes of his many guests. A great reader, he was also a good conversationalist and had a ready store of wit and anecdote which he larded with warm laughter.

This generosity of character was marked by the strength with which he maintained his family ties, though remaining a bachelor, and by the understanding he gave of the problems of others.

On retirement he settled in Magilligan where in addition to serving as a JP, as High Sheriff of Co Londonderry and as an active member of his Parish Church, he set himself to plant and cultivate a wonderful collection of flowering shrubs and trees.

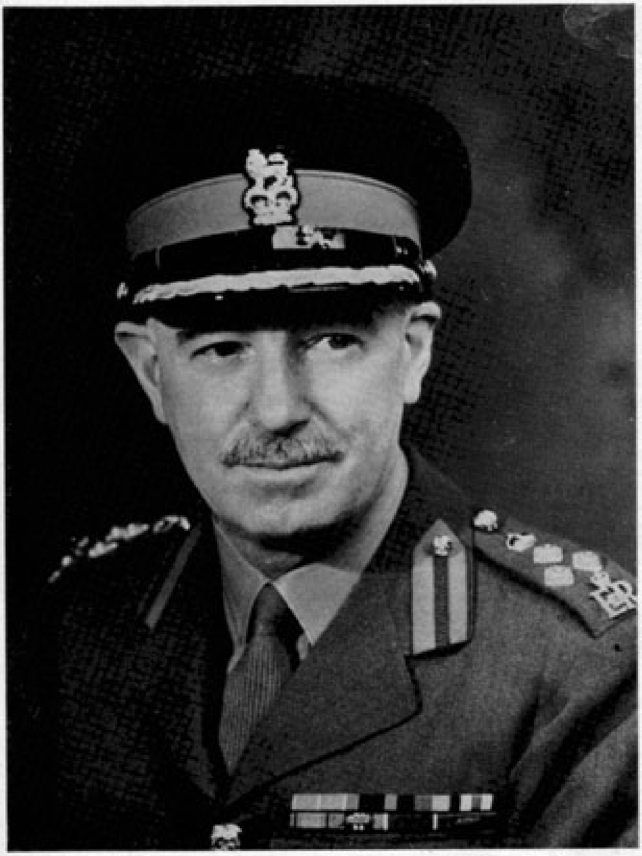
HTH

A contemporary of Ted Heard recalls unfailingly happy memories of him spread fairly evenly over fifty-five years starting with bicycle trips out from the "Shop" to golf around Woolwich on courses long since submerged under housing; on through careers not too geographically wide apart, to a final steady flow of letters to and from the delightful County Londonderry homestead of Ted's boyhood which, it is nice to know, remained despite its somewhat sinister postal address of Magilligan, a haven of peace for our distinguished one-time County High Sheriff.

Ted was always damn difficult to beat at golf, or argument! But there was never the least touch of acrimony about it; not between Sappers anyway. At golf while still a YO he played for the Corps. On the Staff he was the first of our batch to make Brigadier; but luckily all round he eventually brought his ability and likeability back to the Corps. He was at his happiest then; an object lesson for Staff aspirants? Another lesson; join the "In-and-Out"; it was always a great delight to bachelor Ted. One quirk; his handwriting remained delightfully indecipherable. My last letter from him a few weeks ago ended: "I find resting a great pleasure". Before replying "me too", I thought to use a magnifying glass; the word was probably "reading".

TILI

Ted was the first commander of the Training Brigade RE then more than 3,000 strong. The standard of National Servicemen posted to units from the three training regiments and the function of the Depot Regiment were his responsibility .He set the standards he expected his CO's to achieve; these were high, he was critical yet did not interfere and his CO's knew they would be supported whole heartedly. The latter was invaluable as both national newspapers and certain MP's were merciless in voicing the complaints of national servicemen regardless of their validity.



An "Annual Inspection" of a unit made by Brigadier Heard will long be remembered by anyone who underwent this ordeal. It was normally a two-day affair when he and his accompanying staff officers would take the unit to bits. The unit would be paraded in marching order and after an initial inspection came the detailed examination, the parade ground took on a strange appearance. "A" Company, front rank sit down, boots off, soles to front, feet straight out. It had to be my batman whose toes smiled through his socks. Then QMSI's were seen to be proving their jacknives to be sharp by whittling wood. Meanwhile the ACC officer was required to put his cooks through foot and arms drill. Barrack rooms, kit, vehicles all received equally meticulous examination.

He was a life long bachelor and an incomparable host whether officially or privately at his quaint little quarter Gozo Cottage, next of course Malta Barracks,

Brigadier L F Heard CBE.

and again latterly at Magilligan where he spent his retirement; he was a keen gardener and a good cook.

He was abrupt, ruthlessly efficient and he had a superb brain. But underneath a somewhat austere mien, there was wit, humour and charm; he was an engaging companion on any occasion. Those who served under him must owe something to his splendid example.

HWK

Book Reviews

DECISIVE BATTLES OF THE TWENTIETH CENTURY: LAND—SEA—AIR

EDITED BY NOBLE FRANKLAND AND CHRISTOPHER DAWLING
(Published by Sidgwick and Jackson, London: 348 pages: Price £7·50)

So many indifferent books are produced today—your reviewer himself has published works that he would not recommend to his worst enemy—that it is a real pleasure to pick up a book which, in spite of a high cost, he can wholeheartedly commend to military readers.

Decisive Battles of the Twentieth Century demands respect for two main reasons. First, because the Editors, Noble Frankland and Christopher Dawling, have chosen the twenty-three battles they consider decisive with judicious ingenuity; and secondly, they have captured authors of outstanding ability to write about them.

The choice of battles hinges upon the interpretation you give to the word "decisive" in this context. What makes a battle decisive? At first sight you might say that a battle is only decisive when one side gains a complete victory and the other is utterly defeated. Those holding that view would concur in the inclusion of Dien Bien Phu: but they would not agree that Jutland was a decisive battle. The Editors, however, might retort that a decisive victory and a decisive battle are not always the same thing. Neither the Grand Fleet nor the German High Seas Fleet won a decisive victory at Jutland, but the consequences of the battle were certainly decisive; for thereafter the Grand Fleet was never again challenged. The Germans resorted to U-boat warfare, and abandoned the only possible way that existed of winning the war "in an afternoon"—to quote a Churchillian phrase.

Some of the battles chosen are not well known. Your reviewer would hazard a guess that even amongst relatively well-informed readers there is only one in five who knows much about the air battle of Schweinfurt, fought over German occupied Europe on 14 October 1943. Yet when the fighters of the Luftwaffe shot down about half of the American daylight bombers that set out from England to attack the ball-bearing factory at Schweinfurt, they gained an obvious victory, but thereafter the course of the air war turned immediately against them. The reasoning is complex, but sound. The battle demonstrated two things. The first, which some might deem self-evident, was that "despite the wonderful determination of the American crews . . . unescorted, self-defending, daylight bomber formation attacks upon major German targets were not a practicable proposition of war". Secondly, it showed that long range fighters—which happened to be available in the form of several types already in production (notably Mustangs) and which only needed the simple modification of disposable fuel tanks—could change the whole scene. A balanced force of daylight bombers and long range fighters could attack any target they chose, and in so doing they would bring up the German fighters to be destroyed in combat against superior numbers, while the attack was accurately made. This was a decisive turn of events from which flowed the winning of the air battle before the land battles of Europe in 1944 began.

Another interesting choice of battle is the Tet Offensive in 1968. As the Author points out, it was hardly a battle at all in the usually accepted sense; and it was an undoubted tactical failure for the Viet Cong, yet it "actually caused the beginning of the end of American participation in the Viet Nam War". The results of this battle were in the fields of politics and psychology; and a study of it by those brought up in the Clausewitz tradition may be something of an eye-opener.

Perhaps the most difficult battle in this book to bring to life in the written word is the battle of the Atlantic. There were a few highlights, such as the sinking of the *Bismarck*, but in the main it was an unseen struggle over wide expanses of ocean, with little to show but the tell-tale graphs of sinkings. It was a matter of constant vigilance, human endurance and valour, and the skill of the antagonists to bring their resources to bear. But it was certainly decisive, and it is well told by Stephen Roskill.

Amongst the battles in this book there are two that concern the air only. There are six sea battles and fifteen land battles; but it must be remembered that since 1914 the air arm has played a steadily increasing part in all of them to the extent that it is not always easy to decide whether the air or one of the older services played the greater part. Pearl Harbor (the book's spelling) is a case in point.

Now perhaps a few words about the Authors. Your reviewer must first say he gives pride of place to a serving Sapper—General Jackson—for his account of El Alamein. This is not entirely a mark of fraternal solidarity. It is because this is a much debated battle and one that excites considerable controversy. The Author, however, puts it all in decent perspective, and—perhaps more than any other of the Authors—he indicates the fog of war and the way that decisions must sometimes be made by commanders on very slender, or even false, evidence.

Other Authors whom your reviewer much enjoyed reading included Sir John Wheeler-Bennett on Tannenberg and Alan Palmer on the Battle of the Marne. Both these well-documented battles arouse conflicting opinions and are in themselves dramatic stories; and both these Authors seem to have dealt particularly skilfully with them. Most of the Authors are British; but five Americans and one Australian ensure a certain variety in outlook, style and spelling.

Beyond this, your reviewer is reluctant to single out others. The reader must read the book himself. There are good maps and he is likely to be kept up much too late at night reading; and when he has finished, he will feel as though a good companion had departed.

MCAH

THE TELEGRAPHS

GEOFFREY WILSON

(Published by Phillimore & Co Ltd London & Chichester, Price £7·50)

THE author gives us a comprehensive history of the shutter, semaphore and other kinds of visual mechanical telegraphs developed in the late eighteenth and early nineteenth centuries. He has drawn on many original sources to provide a great deal of information not previously published and draws attention to a surprising number of physical remains, surviving to remind the archaeologist, the topographer and the local historian of the world's first rapid, regular, message transmitting services.

We are also reminded of the inventive genius of General Sir Charles William Pasley KCB, the first Director of the RE Establishment Chatham (now the RSME), whose "Universal Telegraph for Day and Night Signals" was, in 1826, accepted by an Admiralty Committee, with two minor modifications, as a substitute for Popham's telegraph on ships. It therefore came about that a Sapper officer became responsible for the general form of telegraph at sea which the Royal Navy adopted and proliferated in Victorian days.

JES

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