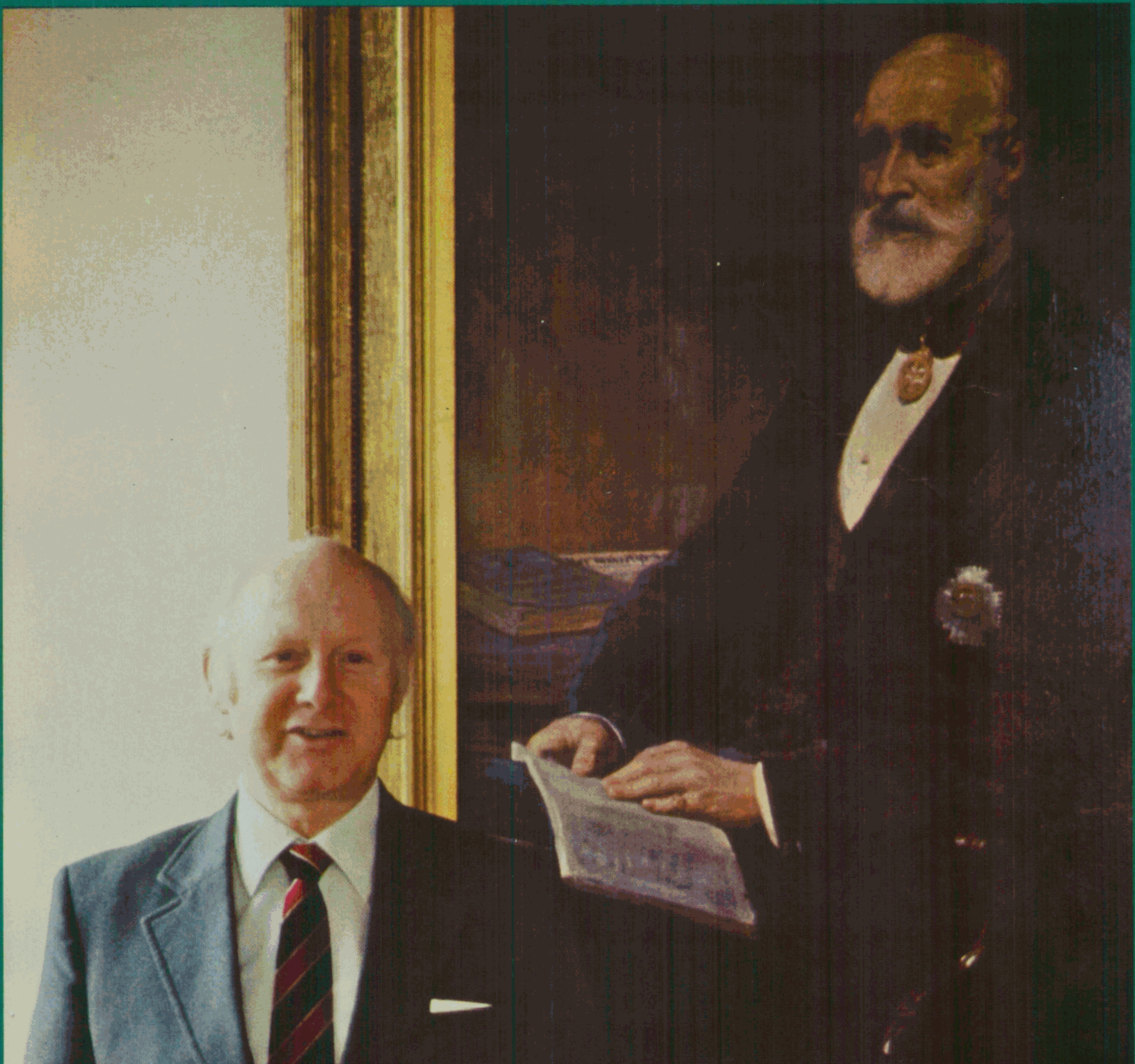
HOSPITAL ENGINEERING

March 1977

International Federation Issue

The Journal of the Institute of Hospital Engineering



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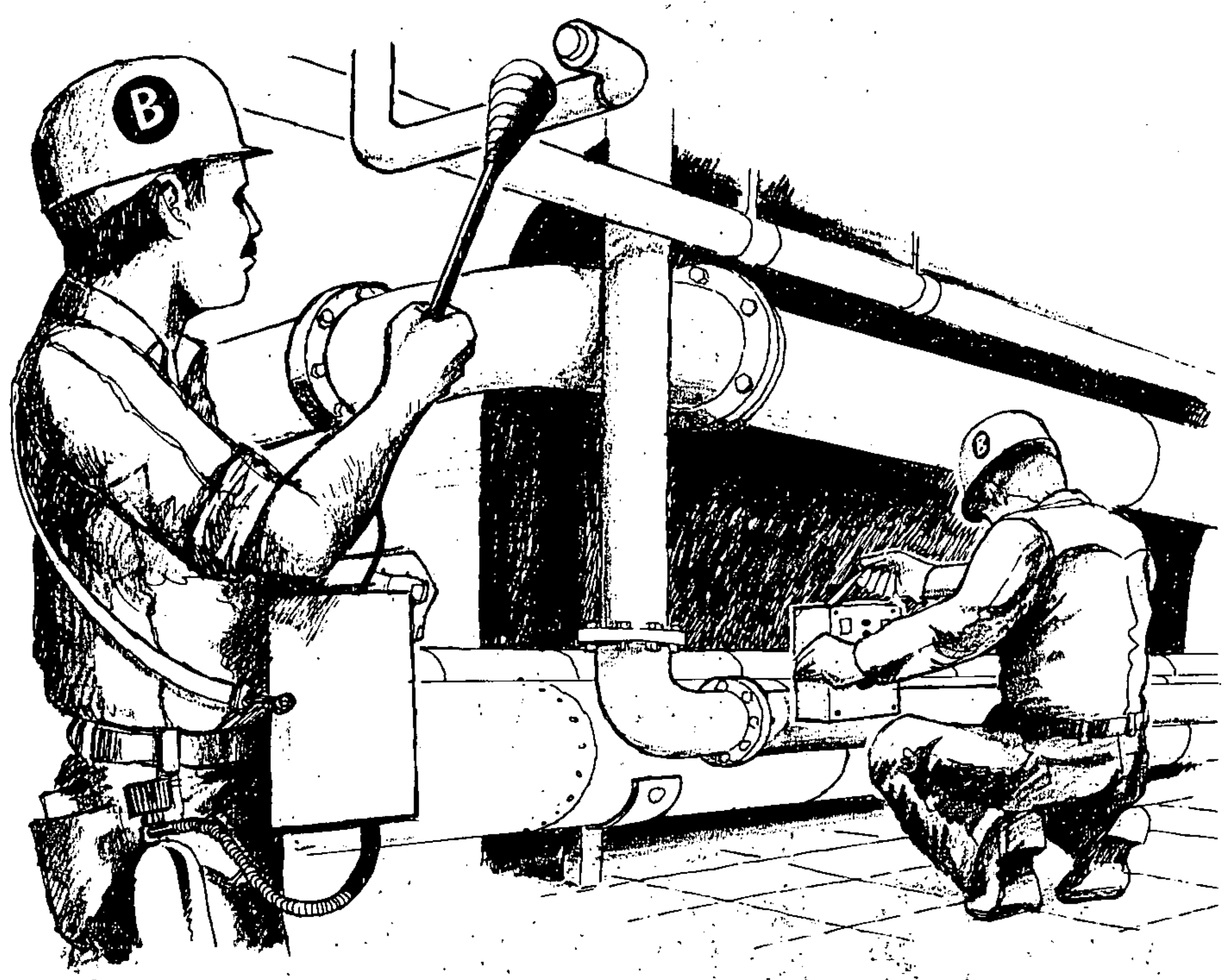

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HOSPITAL ENGINEERING

March 1977 **Vol. 31 No. 2**

The Journal of the Institute of Hospital Engineering

International Federation Issue No. 21

Contents

Institute News

John Bolton
The first DHSS Chief Works Officer

On March 1 of this year the new post of Chief Works Officer was created at the Department of Health and Social Security. It is naturally of great pleasure to the members of the Institute that the man chosen to be the first to fill the new appointment is a member — and a well-known one.

John Bolton, LlB, CEng, FICE, FIMechE, FInstF, FIArb, has since 1969 been Chief Engineer at the DHSS. As such he is head of the Engineers' Division, where he has been responsible for advising on all aspects of design, safety, maintenance and operation of engineering and associated services for hospitals and local authority health and welfare buildings. Now he will take on responsibility for controlling the activities of that division, together with the architects, surveyors and health building divisions of the Department.

Mr. Bolton is 51 years of age. He joined the National Health Service in 1954 as Group Engineer to the West Manchester Hospital Management Committee, later becoming Chief Engineer to the Board of Governors of the United Liverpool Hospitals, and then moving to Leeds as a Deputy Regional Engineer to the Regional Hospital Board. In 1965 he became Regional Engineer to the East Anglian Board, leaving four years later to go to the DHSS. Our cover photograph shows him in his office in Euston Tower, in front of the portrait of Sir Robert Rawlinson, KCB, 1810-1898, who in a way is his predecessor. Sir Robert was Secretary and first Chief Engineer to the Local Government Board, the forerunner of the Ministry of Health. He had also been the Secretary to the Crimean War Commission and was President of the Institution of Civil Engineers for 1894/5.

Mr. Bolton was born in Lancashire, at Great Harwood. He went to Blackburn College of Technology and Art, and then served a mechanical engineering apprenticeship with the Bristol Aeroplane Company and a civil engineering pupillage with Courtaulds. He spent some time in industry after qualifying, both with English Electric and the North Western Gas Board before joining the Health Service. He regards the experience that he gained before coming into the Service as invaluable to him now. He is obviously a man of great determination, as demonstrated by his possession of a law degree for which he read as an external student years after leaving full-time education. He feels he is possibly unique, in that, so far as he knows, he is the only officer who has been right through the service — a breadth of experience which naturally stands him in good stead and as he says, has always helped him to appreciate the feelings of people at all levels. He is philosophical about the upheavals that he and his family had to go through during his career, although he is glad to have settled — he hopes for good — at Little Shelford on the edge of Cambridge, where they moved in 1965. With three daughters he regards himself as 'outvoted' at home, but is in fact obviously very happy to be there whenever he can. He has entered into the life of the local community, being a sidesman at the local church, where he reads lessons from time to time, and is school manager of the local school for the twin villages of Great and Little Shelford. He does a little gardening, but his chief relaxations are reading widely, and going to the theatre whenever he can manage it.

Talking of his new role, he is obviously fascinated by its complexity. As he says, building and engineering in the Health Service is extremely complex. The Service is the largest launderer and largest caterer in the country. It has its own electricity generating and water catchment and treatment plants. The engineering aspects of building works for hospital purposes account for no less than 40% of the total costs. Building and engineering staff in the Health Service find themselves working in areas unique to their calling. He stresses with some pride the pre-eminent position throughout the world that the British Health Service has. He himself has been involved with advising foreign governments in Nigeria and Saudi Arabia for example, and has also had a great deal to do with the setting-up and running of the Hospital Engineering Training Centre at Falfield, which is the only such nationally run centre in the world.

He sees his new post as being chiefly concerned with the management of multi-Disciplinary Divisions, and with making recommendations on works policy as part of the team at the very top of the Health Service. It is not necessarily a job in which things can be done overnight and Mr. Bolton recognises he must take the long view. Although he regrets to some extent the move even further away from the intricate detail that is any engineer's joy, he finds compensations in the wider aspects of his work, and certainly can live very happily with the need to deal with Parliamentary Questions or Ministerial correspondence, that is the lot of the Senior Administrator. It is clear that, in this difficult new post, the Department has a man with the necessary breadth of experience and of vision. We wish him every success.

The International Federation Journal

A message from the Chairman of the Publications Committee

The International Federation of Hospital Engineering is now in its sixth year of what has been a rapid and successful period of development. The basic reason for the success of the International Federation so far is that it has satisfied the need for communication between groups of professional people with similar interests, aims and objectives in the field of hospital engineering and associated activities.

So far our enthusiasm has overcome the problems of language and distance between our constituent members and we have managed to build a comradeship and understanding through individual communication and personal contact at our International Congresses and Council Meetings.

However, the IFHE has now reached a stage of development where our infrequent collective meetings and other methods of communication may be insufficient to maintain the interest and enthusiasm of our members and to promote the further development of our organisation.

We should all be sorry to see a decline in interest and influence of the International Federation but to guard against this we must consolidate and improve our methods of communication in line with our original aims and objectives.

Apart from the official channel for correspondence through the General Secretary, Bruno Massara, we have at our disposal the facilities of this Journal which is published four times each year, now in March, June, September and December. The Journal has worldwide distribution, not only to member countries associated with IFHE but also to many individuals in other countries.

Contributions for publication in the Journal may take the form of:

(i) technical papers dealing with hospital engineering or any other matter associated with health care and hospitals that members may be involved with:

(ii) General topics of information about the activities of your organisation or its individual members;

(iii) General matters concerning development of hospitals and health care in your country;

(i) A 'post-box' seeking through correspondence, the answers to questions or general comment on problems confronting hospital engineers and associated professions in your country.

Let us all endeavour to make the international issues of the Journal our principle means of communication as a foundation for ensuring the continued success of our personal contact at Council Meetings and Congress.

All contributions to the Journal may be channelled through the General Secretary, Bruno Massara, or directly to: Mr. K. W. Ashton, 3 Fernwood Road, Sutton Coldfield, West Midlands B73 5BG, England, who acts as Chairman of a Publications Committee for the Journal and will arrange for publication.

Portuguese Association of Hospital Engineering

The 1977 calendar of activities of the Association is:

19 April **Sterilisation** M. Ferraz da Costa;

20 May **Study visit to New Castelo Branco Hospital** Discussions;

14 June **The Hæmo-Dialysis Department** Eng. Tec. J. Mealha;

11 October **The Problem of the Neutre in Electrical Installations** Garcia Vasquez;

15 December **Operating Theatres** Eng. Eduardo Cætano.

All meetings will be held in Lisbon at the Instituto Nacional de Saúde Dr. Ricardo Jorge, Avenue Padre Cruz, except on 15 December, which will take place in Oporto.

James Bolton retires

James Bolton has retired from his post as Hospital Engineer at the Preston Royal Infirmary after 49 years' service, and our good wishes go to him for a most happy retirement which he has surely earned.

Five-Branch Meeting

This year's Five-Branch Meeting between the London, Midlands, Southern, South West and East Anglia Branches will again be held in London. The meeting will be at the Middlesex Hospital, School of Medicine on May 21 and members are asked to make a note in their diaries. One of the proposed papers for this meeting is 'The Pollution of Operating Theatres by Anaesthetic Gases'. Full details of the day's programme will be circulated by Branch Secretaries in due course.

Electrotechnology in Modern Medicine

On March 21 the Institution of Electrical and Electronics Technician Engineers is arranging a lecture meeting on the subject of 'Electrotechnology in Modern Medicine' at which the speaker will be Professor T. Shelley, Regional Head of Physics, Wessex Regional Health Authority. The meeting will take place in the IEE Building, Savoy Place, London WC2, at 6 p.m. Tea will be served at 5.30 pm.

Members interested in attending should contact the Secretary, Mr. A. C. Gingell, at Savoy Place — telephone: 01-836 3357.

Institute ties

In response to several requests, a new stock of Institute ties has been ordered where the 'blade' of the tie is somewhat wider than hitherto, to accord with changing fashion.

As is known, the tie is stocked in either navy blue or maroon and bears once the centrepiece of the Armorial Bearings. Orders please, to the Secretary, the Institute of Hospital Engineering, 20 Landport Terrace, Southsea PO1 2RG, stating colour required and enclosing remittance to cover cost at £1.50 per tie.

Obituaries

We regret to report that four members of the Institute have died recently. Of them, perhaps the widest known was Jack Deen. An old friend writes:

Jack Deen served his time in electrical contracting and worked mainly in London, or for London contractors, and first came to Sheffield Region as Site Engineer for Brian Colquhoun, who were Consulting Engineers for Doncaster Royal Infirmary. He joined the staff of Sheffield Regional Hospital Board as Site Engineer for that hospital on November 1 1964.

During this time, Barnsley District General Hospital was being planned and he spent part of his time from the middle of 1967 at both Barnsley and Doncaster. On the completion of the Doncaster project, he came to Barnsley full-time.

He finally retired as Site Engineer at the end of August 1974.

He was very interested in electrical safety and made a few amateur films to demonstrate to others electric shock risks. He had many friends and took a great interest in training others.

Incidentally, he was one of the early visiting tutors to the first 'Keele' course, organised by the Institute of Hospital Engineers for assistant engineers. Doncaster Royal Infirmary was one of the hospitals visited in those early days and Jack Deen described the services and his part in the project.

He leaves many friends in Yorkshire. *A E*

We are most sorry to record the deaths of two long-serving members of the Institute, Mr. H. L. Wright of Beckenham, and Mr. G. Kirby of Bradford.

Mr. Wright's contributions to Institute life will be remembered by all his erstwhile colleagues in the London Branch, and elsewhere.

Mr. Kirby, who was Hospital Engineer at the Bradford Royal Infirmary was a very keen and active member of the Yorkshire Branch over a period of many years.

Also, Lieutenant B. Pragnell, RN (Retd), who was Hospital Engineer at Northwick Park Hospital, Harrow for a number of years before moving down to Wiltshire, died on January 8 1977.

Book Reviews

IEE Medical Electronics — Monographs 18-22
Edited by: D. W. Hill and B. W. Watson; contributions by: B. H. Brown, J. Brydon, L. D. Geddes, R. E. Gosling, P. Rolfe.
Price: UK — £10.90; Overseas — £12.75 (excluding America).

In line with the policy adopted for the previous three volumes 1-6, 7-12 and 13-17, this fourth work 18-22 contains about half-a-dozen short monographs on a broad spectrum of subjects of current interest and practical importance in medical electronics.

Once again in this series the authors have produced a well written and well put-together book covering a range of subjects that are of interest to a wide range of people involved in the field of medical electronics.

The many and varied illustrations included are clear and easily understood, and the use of mathematical formulae is kept to a minimum without missing out any necessary information. A comprehensive list of references is given at the end of each section for readers who require more technical detail on a particular subject.

This book will make a valuable source of reference to a broad spectrum of doctors, physicists, engineers and technicians associated with medical electronics. R G S

Materials of Construction for Steam Power Plant
by L. M. Wyatt. Published by Applied Science Publishers Ltd. Price £15.00.

The author of this book is the Chief Metallurgist at the Research Laboratory of The Central Electricity Generating Board. It is evident that Mr. Wyatt is an expert in this subject, but he deals with the various problems in a most practical way. He covers in considerable depth the problems encountered in designing, building and operating modern power stations, utilising both nuclear and fossilised fuels. In many instances the metallurgical solutions to the problems are given. Many of the present generation sets by nuclear reactors are discussed, as is the effect of the radioactive environment on a large range of materials.

The Author makes reference to all the major items of plant to be found in a modern generating station, i.e. steam generators, turbo alternators, circulating pumps and feed pumps. The development of special alloy steels and alloys of magnesium and zirconium, the latter two being used for fuel cores in nuclear reactors, have several chapters devoted to them. The book is extensively illustrated, and has a considerable number of photo-micrographs.

Welding problems are dealt with in the chapter on fabrication, as are steel making processes. The chapter on water and fireside corrosion is particularly interesting to readers involved in Hospital Engineering.

This book makes very interesting reading, but can only be really appreciated by those whose knowledge of metallurgy is fairly extensive. R G S

In this updating of his paper presented last June and published in Hospital Engineering, *October 1976, Mr. Howorth shows that levels of anaesthetic gas pollution require urgent attention.*

Anaesthetic Gas Pollution - II

F. H. HOWORTH FRSA FInstPI FIIC PIHospE

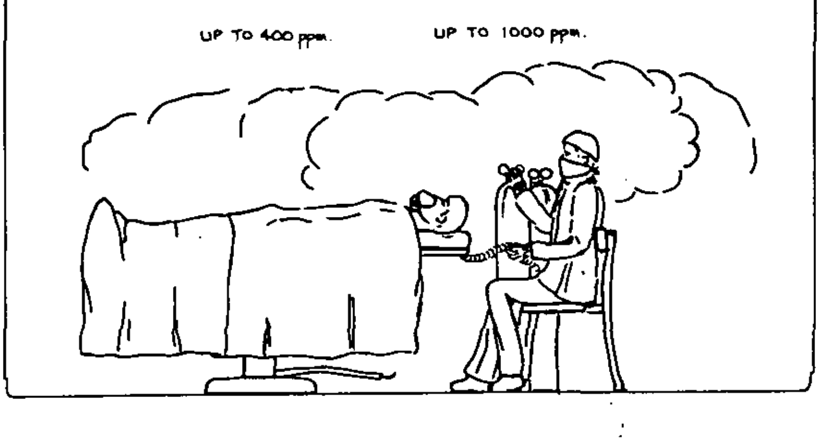
Since my paper was presented on this subject in June 1976, we have surveyed a large number of operating suites to continue to quantify the anaesthetic gas pollution and study its behaviour patterns. The results demand the most serious attention.

When we purchased our IR gas analyser early in 1975, we knew that the United States regarded 30 ppm as the maximum safe level of N_2O. Since there is usually around 4½% Halothane in the N_2O, its level of concentration can be easily calculated. It was also seen to be much simpler to find accurately the behaviour patterns of the larger volume of N_2O rather than the smaller volume of Halothane.

It seemed logical that an analyser reading up to 250 ppm would be adequate, as this would be eight times the recommended safe level of pollution. However, on many occasions the pointer went quickly across the dial and rested firmly on the limit pin beyond the 250 ppm level, so that we had to estimate the concentration by watching the speed of deflection of the pointer. Eventually we returned the analyser to the suppliers and had the range increased to read up to 1000 ppm.

Continuing our gas pollution surveys, we were very surprised to find that on several occasions there were readings of 1000 ppm covering a

Figure 1



radius of four feet from the patient's face or the anaesthetic machine, and at a level of between three and five feet from the floor. This is the zone from which members of the surgical team and the anaesthetist are inhaling (see *Figure 1*).

The implications are particularly serious when we realise that theatre personnel often inhale these high concentrations of anaesthetic gases for several hours at least five days per week. As well as the health hazard, there is the inevitable reduction in the performance of their skills and in their concentration, not only while in the operating theatre, but even while driving their cars home afterwards.

The behaviour pattern of the N_2O (and therefore the Halothane) is also interesting. Anaesthetic gases are heavier than air, when they are at the same temperature as the air, but gases which have been inhaled and exhaled are warmer than the ambient air and are no longer heavier than it, they just hang around like an invisible cloud. The effect of convection up-currents from the warm patient, and the even warmer members of the surgical team and the operating lights etc., make quite sure that these gases do not fall to the floor, as had generally been supposed.

We know from our 1962 research when the Charnley-Howorth sterile operating unit was designed, that a minimum unidirectional downflow velocity of 50ft/min is necessary to oppose these convection up-currents when the operating lights are switched on and when there are people in the theatre. This required velocity falls to about 30ft/min to oppose convection up-currents when the lights are off and the theatre is not in use. This is why we have two speeds on our sterile operating units, i.e. 65 to 70ft/min when the theatre is in use, and half that speed when it is not in use.

When these air flow speeds are related to volume it will be seen that the air changes in our sterile enclosures are just over 300 per hour on normal speed. I quote these figures to show how impossible it is for a conventional air-conditioning system giving 20 air changes per hour to make much impression on these convection up-currents. Twenty air changes per hour will adequately control temperature and humidity in an operating room, but will not really establish either a regular, or even a predictable air pattern, and certainly not a unidirectional downward flow or 'piston effect'.

The diagonal flow diffusion system often found in theatres, where air enters high upon one wall, and goes out low down on the opposite wall, has a strange effect on N_2O. The N_2O moves to the exit wall where it builds up into an invisible cloud and then rolls around above the air outlets like a wave continually breaking on the shore (see *Figure 2*).

In all the theatres which we have surveyed, an active scavenging system was seen to be the only way to remove this surprisingly large amount of anaesthetic gas pollution satisfactorily.

Let us examine, therefore, what is permissible for patient safety, and what is required to be done by hospital engineers to make available an effective and safe scavenging system for connection by the anaesthetist, either to the anaesthetic circuit, the machine or to the patient ventilator.

The draft British Standard Specification for active scavenging systems lays down that the maximum negative or positive pressure at the respiratory system shall not be more than 0.5 cm H_2O when measured at a flow rate of 30 litres per minute.

This system, which was illustrated in the October 1976 issue of *Hospital Engineering*, has three exhaust points; induction room, operating room and recovery room.

Because the face cone used in the recovery room is not directly connected to the anaesthetic circuit or the machine, the BSS does not apply, and at that position, a much larger volume of exhaust is both necessary and permissible.

At one of the new installations of this system (Blackpool) we measured the greatest negative pressure to be 0.1 cm H_2O with a flow rate of 125 litres per minute. This is when there is an assistance to the active scavenging system, and under this condition, there was no difficulty in taking away 150 litres per minute when measured at a constant flow rate.

A patient on a ventilator could exhale a maximum of 150 litres per minute, but this will only be during intermittent peaks, and is, therefore, an adequate volume.

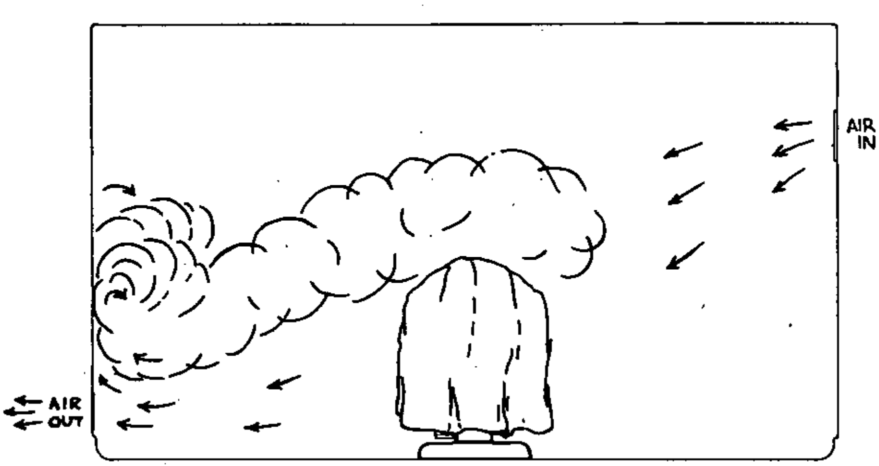
Condensation is not a problem in a system in which there is approximately a ten to one dilution of exhaled breath at the 'break-point', that is where the flexible pipe connects to the wall or ceiling pendant.

There is no risk of explosion in a system where there is this high dilution and where the exhauster is a centrifugal fan with a spark-proof impellor, and the drive motor is outside the air flow.

Excessive exhaust pressure is not possible with this system because of the characteristics of the centrifugal fan related to the characteristics of the piping system. Unlike a positive displacement exhauster, a centrifugal fan will not fight for air and this one gives up the fight very easily.

It should be pointed out that if there are several theatre suites in one hospital, it is preferable to have one active scavenging unit to each group of three exhaust points, for instance, induction room, operating room and recovery room. The reason for this is that in the event of there being only one theatre suite in use on certain occasions, then no imbalance of the system can occur. If, however, there is only one main exhauster for perhaps six or eight theatre suites, then

Figure 2



when there is only one in use, there would be considerable imbalance, and even if this is allowed for by safety valves, the noise would be quite unacceptable.

Anaesthetic machines and circuits are not the responsibility of the hospital engineer. However, the anaesthetic machine, or circuit, should have a pressure relief valve which releases at 0.5 cm H_2O. Conveniently, it should be as part of the scavenge valve or on the anaesthetic machine discharge point, so that, if the scavenge exhaust route should accidentally be occluded, then the patient exhales through this relief valve.

This, like the scavenge valve, is the responsibility of the anaesthetic machinery manufacturers. I believe that the responsibility of the hospital engineer finishes with the active scavenge pipe. It may then be connected by the anaesthetists by whatever means is suitable to the various types of exhaust points of the anaesthetic equipment.

It is the responsibility of the anaesthetists:

1. to be sure that the face mask, or cuff, fits properly;
2. to be sure that the machine has no gas leaks;
3. to use his anaesthetic equipment so that exhaled escaping gases are channelled into the active scavenging system.

For recovery and certain surgical operations, special exhaust cones of different shapes may be required, and can easily be produced and fitted by us to sketches supplied by the anaesthetists.

This summary of our experience, it is hoped, will be of guidance to hospital engineers who are certainly going to be faced with satisfying these requirements.

Mr. de Vries is with the National Hospital Institute of the Netherlands, section architecture and technique, Utrecht, and has been a member of the board of the Dutch Institute of Hospital Engineers (NVZT) for many years.

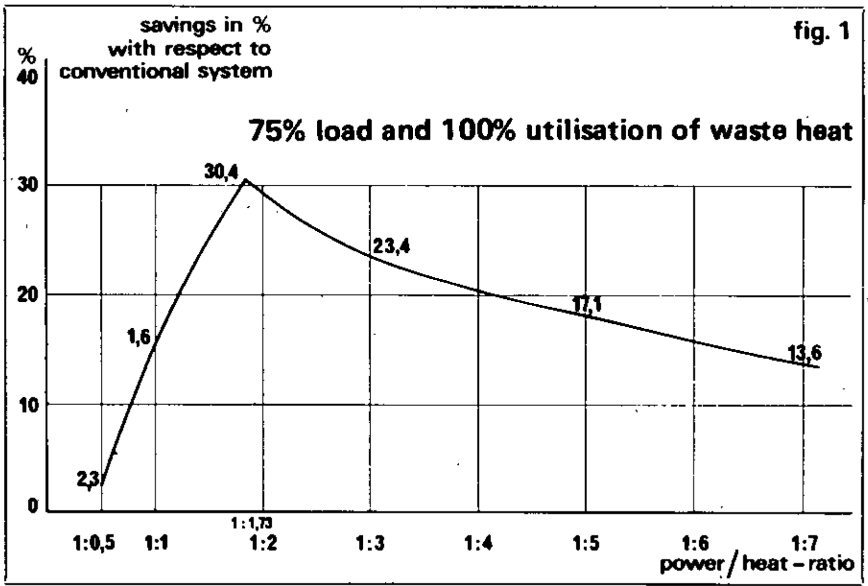
In this article he shows the possibilities of considerable energy savings by means of a combination of 'total energy' and the heat pump process.

A new Concept of Energy Supply for Hospitals

J. de VRIES ING MIHospE

Energy consumption in hospitals

The energy consumption in hospitals during the last ten years has increased considerably. In an investigation which I made for the Netherlands National Hospital Institute, the heat consumption was found to have increased from 70 Kcal × 10^3/patient/day to about 90-100 Kcal × 10^3/patient/day. Electricity consumption, however, increased from 10-11 Kwh/patient/day to about 30 Kwh/patient/day. In this investigation I have tried to relate energy consumption to the use of air-conditioning. In this case-study three types of modern hospital, constructed between 1969 and 1974 have been selected and their energy consumptions related starting with the extent to which air-conditioning is used in the hospitals concerned. The relation between consumptions can be expressed in the proportions 1 : 1.48 : 1.85 for the heat consumption, and 1 : 2.05 : 2.45 for the electricity consumption. A remarkable fact that has been proved is the comparison between heat and electricity consumption (expressed in the same values). This comparison has changed from about 8 : 1 to about 3 : 1. The lower figure refers to those hospitals which have comprehensive air-conditioning installations. Consequently we can state that the increase in electricity consumption is much higher than the increase in heat consumption, and that 'total-energy' can reach a higher efficiency in those hospitals equipped with air-conditioning, as shown in *Figure 1*.



It is not the intention to go into the pros and cons of air-conditioning. Regarding energy consumption: it has become obvious that something has to be done about the improvement of the physical quality of the buildings (heat isolation and accumulation, and good outside protection against the sun in summertime).

The intention of this article is to point out the growing consumption of energy, and the importance of using methods which can be employed to decrease energy consumption by improving the thermal efficiency in combination with recovery of heat.

Experiences with 'total-energy' installations

Over the years many articles about 'total-energy' have been published, in which the pros and cons have been fully expounded. Meanwhile, four hospitals in the Netherlands have been equipped with 'total-energy' installations, and I have included these in the above-mentioned investigation. The oldest installation has been in use since 1972. This installation was originally set up as an 'island system' but has been made into a so-called 'selective energy system'. Two other installations are likewise making use of selective energy, which means a connection of limited capacity with the local electricity mains. The hospitals for which the installations are intended have a capacity of:

Year introduced	*Number of beds*	*Number and capacity of generators*
1972	480	3×550=1650 kVA
1974	350	3×730=2190 kVA
1974	460	3×800=2400 kVA

All gas-ignition engines are US made (Caterpillar, Waukesha). The fourth installation, of a much larger capacity, has been set up in the 'Free University' in Amsterdam. This installation consists of six generators, 1100 kVA each, driven by 'dual fuel' engines, made in Britain (Ruston). The installation supplies about half of the electricity demand and works in parallel with the local power station. The hospital, however, has been connected as a priority user. This concept gives the hospital a high level of reliability as far as the supply of electricity is concerned.

There is no doubt that 'total-energy' promotes the more efficient use of scarce fossil fuels. This is a factor of general interest, but more interesting as far as the hospitals are concerned is economical management. This interest can be explained by inflation and the difficulty of limiting the costs of running a hospital. Many estimates have been made as to the economic value of 'total-energy' but in my opinion the facts remain somewhat indistinct. On the profit side, there is a growing need for 'non-breakable installations'. especially in the conventional hospitals, for the OP and special care departments — a factor which in many comparison-calculations has not been taken into consideration. With selective-energy the undesirable starting time of emergency generators has been eliminated. The cost of fairly expensive 'no-break' sets could be saved. On the debit side are the costs of maintenance of a 'total-energy' installation which can rise to unexpected heights, and the continuous debate over the number of extra engineers required to keep the engines in good running condition. Furthermore, the profits are directly dependent on the gas and electricity rates. Alterations in these rates, based on political decisions, will influence the share of profit (or loss). It appears that, to this day, the rate of profits has been such that the above-mentioned alterations are of immediate relevance, at least in the Netherlands.

Provisional calculations for two of the above-mentioned installations produced the figures given in the table below.

Summing up all considerations of selective energy in the Netherlands, I came to the careful conclusion that with the present rates for gas and electricity, plus the extra costs for emergency connections to the local electricity board, no very high profit can be obtained. It must be said that a relatively high sum has to be paid to the local electricity board for the emergency connection. The most efficient thing would be to obtain a constant supply from the electricity board. These supplies are often used by departments where voltage-fluctuations are undesirable. These extra high costs have of course a negative effect on the profitability of the total installation. Voltage-fluctuations can in my opinion be eliminated by voltage-compensators to suit those special departments. The high rate is also based on the fact that in unfavourable circumstances such as wintertime maximum capacity might be necessary, for instance in case of a breakdown of the hospital's own generators. Where more local installations are employed, the risk of a breakdown of all these installations is considered to be low. On the other hand these installations together could help to reduce the maximum load of the electricity board at special times (peak load reduction). This procedure is of general interest, and on these occasions it would be reasonable if not the high but low rates were to be charged.

The question has been raised as to why a relatively low efficiency rate with both installations (70-72%) and the generator (26%) has been achieved. This is probably owing to the fact that in spite of having an extra connection with the electricity board these installations have been operated with great care. For instance at night there are always two generators in operation, most of the time however at half capacity or less.

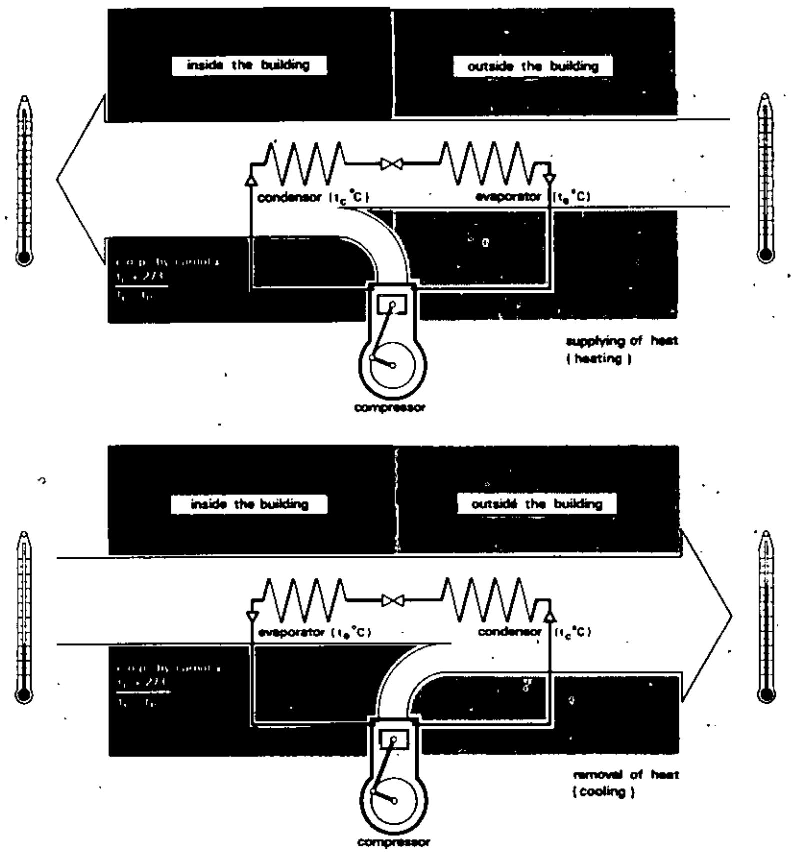
This procedure will have an unfavourable influence on the efficiency achieved. I also have the impression that the total efficiency is influenced

System	*A*	*B*
Total efficiency	70.3%	71.9%
Electrical efficiency	—	26.9%
Efficiency waste heat recovery boiler	—	61.9%
Cost of oil and maintenance	fl. 77,000	101,000
Extra personnel costs	fl. 35,000	50,000
Rate of electricity board (all-in)	fl. 0.10/kWh	0.067
Profits (in comparison with conventional installation)	fl. 135,000	nil

Explanation:
In the comparison calculation the costs of connection to the local mains are included; however no costs of emergency-generators or no-break sets have been given over the conventional situation.

unfavourably by the introduction of absorption-cooling. It seems to be logical to utilise waste or surplus heat for cooling purposes in summer time. Though I cannot give figures, I have the impression that the heating energy used for cooling purposes exceeds the heating energy delivered by the waste heat boilers to a considerable extent. In these circumstances expensive cooling energy is supplied by the combination: boiler-absorption cooling. This combination represents a total efficiency of about: $0.85 \times 0.66 = 56\%$. Giving comparative figures, the combination electrically driven compression cooling represents a total efficiency: 0.33×3.5 (CoP) $= 115\%$, which is twice as much as the first mentioned combination. Therefore it would be more important to draw attention to the possibility of using cheap heating energy for other purposes such as: kitchen, laundry, general hot water, hydrotherapy, water distillation etc., than for the introduction of absorption-cooling. Considering the above facts we come to the conclusion that it would be of interest if methods could be found to increase the efficiency for the benefit of total energy systems. In my opinion a great saving of fuel can be obtained by introduction of heat pumps. Before going into this matter it would be useful to explain in a few words the major characteristics of the heat pump.

functional scheme of heat pump process **fig. 2**



The heat pump process

After the energy crisis the heat pump, which works on the well known old principle (Lord Kelvin) of the thermodynamic cycle, aroused great interest. The most important quality of the heat pump is its capacity to use heat to either raise or lower its temperature level. The heat energy which can be raised to a higher temperature level can be withdrawn from endless quantities of, for example heat from the earth, heat from water (rivers or lakes) or heat from free air, which is heat obtained from the sun. Also heat which we indicate as waste heat can be used. This heat will in many cases vary in temperature. *Figure 2* presents a functional scheme of the heat pump process. One of the most interesting characteristics of the heat pump is, that in order to keep it running, a work input is required which is only a part of the heat output. The ratio of input to output can be expressed in the coefficient of performance (CoP). The CoP may be defined as the ratio of its heat output at the higher temperature to the heat equivalent of the work input (electrical or shaft energy) which is required to operate the unit. Another way to view the heat pump is that the heat output equals the heat absorbed at the lower temperature plus the heat equivalent of the work input. For the reverse 'Carnot cycle', this is simply: CoP $= T1/(T1 - T2)$, where: $T1$ = the higher absolute temperature, and $T2$ = the lower absolute temperature.

The practical value will be much lower caused by different losses but one of the most characteristic factors is that heat pump efficiency is directly dependent on the CoP, and this is in turn dependent on the difference of outgoing and incoming temperatures. It will be clear however that temperatures causing condensation and evaporation must be chosen at other temperature levels. If we want to supply water with a temperature of 50°C, the condensation temperature must be at least 55°C. If the available source has a temperature of 10°C it is recommended to maintain the evaporation temperature between 0°C and 5°C. The theoretical CoP in this case will be found to be

$$\frac{273 + 55}{55 - 2} = 6.19.$$

To find the practical CoP we can introduce a value called working grade, which is the figure by which we must multiply the CoP of Carnot. This working grade seems to be dependent on the ratio: T condensor/ T evaporator and will vary from 0.66 to 0.51 for the medium NH_3, from 0.58 to 0.45 for the medium R22, and from 0.55 to 0.43 for the medium R12 (average = 0.50). In the above mentioned example the practical CoP will then be found to be $6.15 \times 0.5 = 3$. The working grade for R22 is in this case exactly 0.5. The CoP practice can vary from 2 to about 6 and by the use of heat pumps it is of the utmost importance that the choice of temperate levels is based on the lowest possible output temperature and the highest input temperature, when heating is the most important purpose. This principle renders the heat pump less useful for central heating systems at very low outside temperature periods, but it seems to be extremely efficient to use waste heat on the input temperature side, this being applicable for the recovery of waste heat. When seen from the primary energy side the heat pump can scarcely be said to gain in comparison with the conventional gas consuming boiler. This is based on the fact that electrical power input represents a total efficiency of 30 to 33% at consumer side. A heat pump must work with a CoP practice of at least 3, to be competitive with the gas consuming boiler. The low rates of gas make it also difficult to render a heat pump economically attractive, in comparison with the use of boilers. When the heat pump is used on the low temperature side, it is known as the refrigerator compressor. This is a very attractive possibility, of using the heat pump in circumstances where heating and cooling are alternatively required, or are even required at one and the same time. See also *Figures 2* and *6*.

Heat pump systems are designed to meet specific requirements. The best known system has a double condenser, so as to able to supply heat, or to remove heat via a cooling tower in case of a heat surplus. Another combination is known as the cascade system. This system fits in quite well in the 'total energy heat pump system', which is why it is used in an illustration (*Figure 3*). In fact this cascade system, which is patented by 'Carrier' consists of two heat pumps, working more or less in serial system. The most important advantages of the specific system are:

in summer time only the low temperature heat pump is in use, so that no high compression is needed and consequently no compressor power is lost;

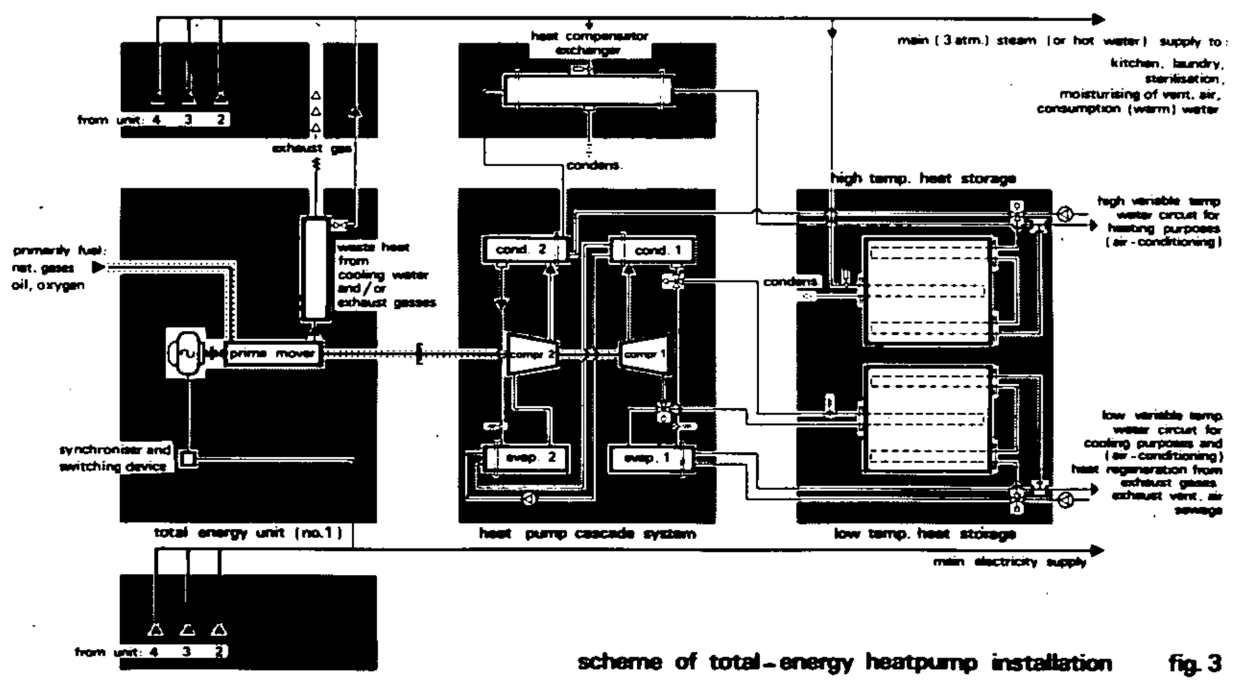
the compression range of both heat pumps is lower than it is when one heat pump is used. The consequence being that normally refrigerating compressors could in many cases be used, thus saving in investment costs;

by using serial produced heat pumps, it is possible to choose different cooling systems. For instance the low temperature heat pump can use freon R11, and the high temperature heat pump is more suitable for the use of freon R113.

It will be clear that individual heat pumps usually need a regulating system in order that conditions be brought into accord with external temperature conditions. It is important therefore that the heat pump works at no higher or lower temperature range than is required by the system of which it forms a part, otherwise the system would have continuously to be brought into balance. It will be obvious therefore that the choice of type and capacity of heat pumps intended for a certain installation is not a simple matter, since it has to do with both heating and cooling, even though it makes up the one compact installation. In my explanation of total energy and the heat pump process I have tried to express that with both systems going separately it will be difficult to obtain any economic profit in comparison with conventional means of heat delivery and electricity supply. In my opinion, however, a combination of both systems in the right number of units, each with a certain capacity, could enlarge the specific advantages of both systems so that a reliable system could be designed in order to obtain considerable energy savings.

The total energy heat pump combination

In principle this combination appears suitable for every kind of energy supply, but in my opinion it would be most useful for compact areas with



scheme of total-energy heatpump installation fig. 3

a relatively high demand for electricity, heating and cooling energy in a certain ratio to each other. This system seems extremely suitable for hospital use as, apart from the above mentioned factors, it has such advantages as heat recovery and an increasing reliability.

The electricity supply is the most essential factor of the installation, because electricity must be generated at the moment of need. The installation can be equipped with units as suggested in *Figure 3*. The most essential property of this system is its capacity to supply electricity, as well as heating and cooling energy by means of the same unit, and where (with special provisions such as heating recovery and heating accumulation), it will be possible to run the unit at full load most of the time. This is of course of importance as far as investment is concerned, as well as regards efficiency results.

Where energy units are to be installed it is quite essential that every unit has its own generator and that every unit in operation has a synchronised generator, possibly running at low load, and at that moment only supplying heat. This makes the installation very reliable, for, in case of emergencies, the heat (or cooling) energy supply units can be disconnected from the heat pump immediately by means of an electric coupling, or by opening a short circuit valve of the heat pump. Power will become available immediately for electricity supply. This arrangement makes the installation very reliable as far as electricity is concerned. Connection to the local electricity board will probably not be necessary.

As a first step it would be most useful to introduce the dual-fuel engine because it can easily switch over from gas to oil consumption. This makes the installation simpler than an installation using propane as a reserve fuel, when gas ignition engines are used. Furthermore the modern low speed two-stroke dual-fuel engines can achieve an overall efficiency of 35% at full load and of 30% even at half load, which is higher than can be obtained with the high speed four-stroke gas ignition engine.

To give an idea of the efficiency which can be obtained with the TE heat-pump system, *Figure 4* (diagrams of energy conversion systems) makes it possible to compare the different systems of energy conversion. In

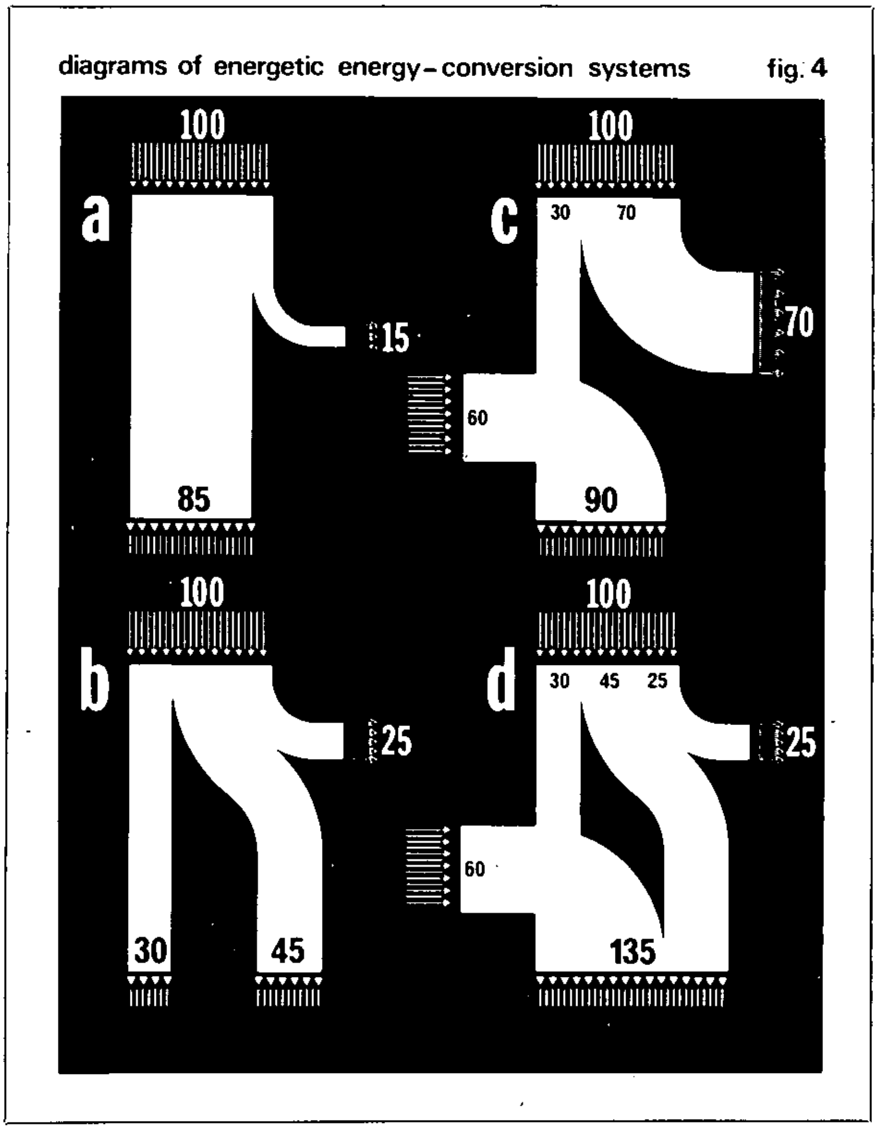


Figure A: Simple boiler system shows boiler efficiency to be 85% in this case.

Figure B: Total energy shows the efficiency of the electricity side to be 30%, the heat gain from cooling water 32%, and from the exhaust gases 13%, totalling 45%.

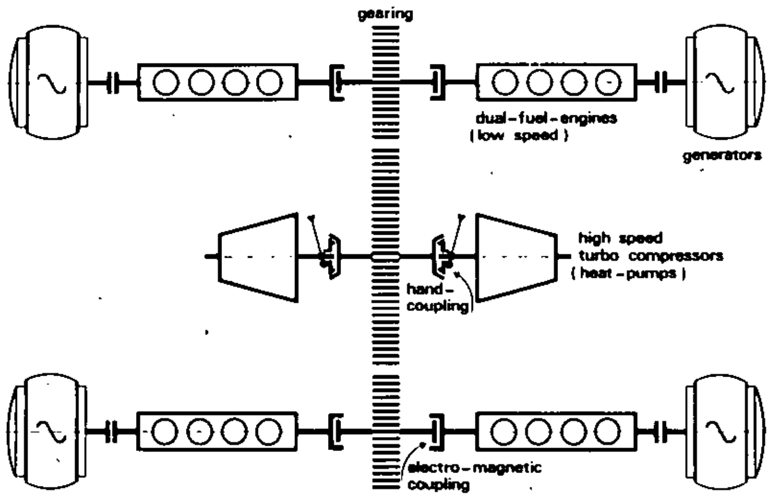
Figure C: Electrically driven heat pump shows an electrical efficiency at the driving side to be 30% (based on the primary fuel). The heat pump operates with a CoP of 3 in this case.

Figure D: Total energy heat pump combination, which is in fact a combination of the systems B + C. In this case the system is expected to supply heat. When electricity is supplied the combination works like system B. The efficiency of 30% means shaftpower efficiency for driving generator or heat pump.

these diagrams the primary energy equals 100; the secondary heat energy from other sources such as waste heat is shown as coming from the left; lost energy is shown going to the right, and the heat available is shown at the bottom of the diagrams.

To simplify the installation, it is for instance possible to install two instead of four heat pumps as shown in *Figure 5*. It is well known however that piston or centrifugal compressors will cause low efficiency results when running at low capacity. It will be more economical to introduce screw or turbo compressors, but these compressors need to operate at high revolutions. Since low-speed prime movers were recommended before, a solution had to be found in which a gearing could be used to increase the revolutions of the heat

example of arrangement: total-energy heat pump units fig. 5



pump. The choice of low-speed piston or high-speed screw compressors, however, also involves cost considerations and is in fact of secondary importance to the principle of the system.

Heat recovery

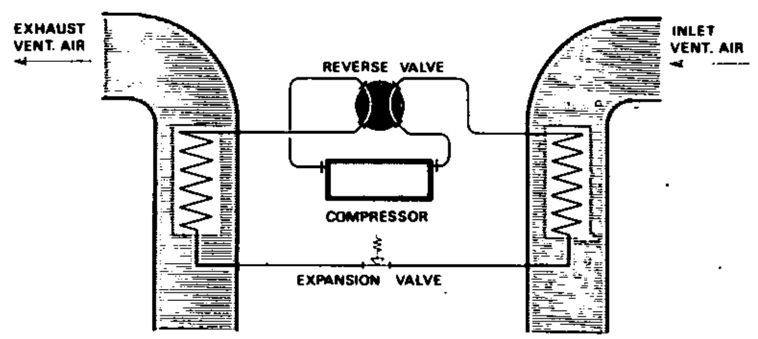
In discussions about energy supply it is good to realise that all heating or cooling energy which we need to keep the interior of the building comfortable must be considered as lost energy, since this energy will escape from the building in one way or another. It is therefore of the utmost importance to make sure that as little as possible of this scarce energy is lost, and we must try to return used energy to the heat supplying cycle. In order to solve the first problem, it is important to take into account the physical quality of the facade and concentrate on protection from the sun in summertime, to keep the cooling energy down. To recover used energy in order to return it to the energy supplying circle seems complicated, and here the heat pump has an important part to play. Recovery of heat is an attractive concept for hospitals, for:

where mechanical ventilation or air-conditioning is used in hospitals it is well known that recirculation of ventilated air cannot be applied because of the danger of contamination. As a result a great quantity of heating or cooling energy is lost in the exhaust air;

as a consequence of hygienic considerations, great quantities of hot or warm water are consumed in hospitals, this also represents a great quantity of lost heat energy;

a certain amount of heating energy is lost through the exhaust gases of installations, such as boilers, prime movers and incinerators. The introduction of the heat pump makes it more attractive to make use of this kind of waste heat.

In *Figure 6*, a schematic example



HEAT – RECOVERY IN CASE OF AIRCONDITIONING
B.M.O. HEAT PUMP SYSTEMS
fig. 6

of heat recovery in air-conditioning is given. It is obvious that either heating or cooling energy could be saved by means of switching the reverse valve. Where the total-energy heat pump is used, heating energy will always be available from the waste heat boiler. However installations intended for hospitals located in tropical or subtropical areas need much more cooling energy. In these circumstances it is useful to take advantage of the cooling energy of the exhaust air. In the following description only recovery of heating energy will be taken into consideration. To obtain the advantage of recovery, additional investments have to be made in pipework and heat exchangers. To reduce these costs it will perhaps be advisable to choose a direct contact-system on the exhaust air and gas side. As a consequence the cooling recovery system will become dirty after a certain time, so that the circulating water must pass through a purification installation. This method is not recommended in those circumstances in which fuels other than clean natural gas are used, because of the danger of extreme corrosion caused by sulphur in fuels such as heavy oil. Using the heat pump process for recovery purposes, one has the important advantage of withdrawing condensed (latent) heat from the exhaust air and possibly from the exhaust gases. With the last possibility one has to be careful because of the danger of sulphuric acid forming. Because of the low temperature of the cooling-recovery water system, condensation of the moisture in the exhaust air will soon take place and latent heat will be regained.

In *Figure 7*, an example of waste heat recovery from exhaust air, exhaust gases and sewage is given.

Heat storage

The advantages of heat storage are:

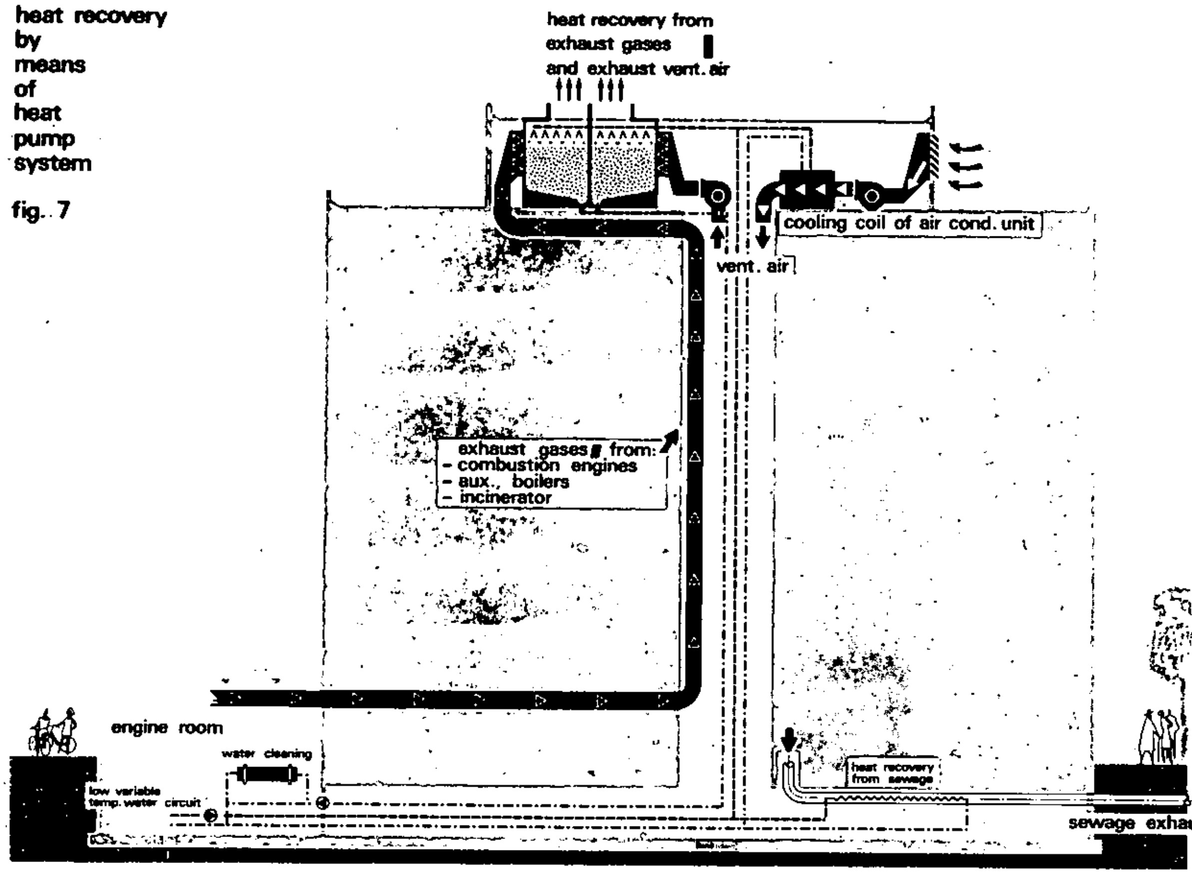
the heat supplying installation can have a smaller capacity, and consequently needs a lower investment;

in case of an interruption in the heat supply no immediate emergency situation will arise.

Should the total energy heat pump system be taken into consideration, the storage of heat has, beside the above mentioned advantages, other attractive possibilities. Since it is possible to change from electricity to heat

heat recovery by means of heat pump system

fig. 7



supply and vice-versa the load of the prime movers could be more constant, and they could then run at their maximum capacity, which in turn will give good efficiency results. Heat storage can be obtained by enlarging the water-circulating system so that a certain amount of heat may be stored in water. For this however, a relatively high investment is needed, since water has a low heat capacity. It is therefore most useful to introduce materials with a reasonably high degree of fusion (melting heat) and here water comes once more into its own. Water is cheap and has a high melting heat of 80 Kcal/kg. On the low temperature side of the system this is an excellent way of low-temperature heat storage. Conveyance of this heat to the high temperature side of the system may be realised by using the heat pump, especially if the so-called cascade heat pump system is introduced. However the installation is arranged in such a way that when the electricity demand is high, the heat pumps must be reduced to low capacity. For this purpose it is best also to have a reasonable quantity of high temperature heat available as heat storage. Having made a small investigation I came to the conclusion that not many materials will answer the following demands to any reasonable extent: high melting point, high melting heat, and last but not least low cost.

The cheapest materials are to be found in the so-called salt hydrates. Unfortunately the melting point of these materials is not very high. Other useful materials are to be found in those compounds uniting carbon and hydrogen atoms in the molecule. These materials are not inexpensive. Some of the most useful materials, as far as I have discovered are mentioned below:

Formula	*Name*	*Melting point*	*Heat of fusion*	*Estimated price*
H_2O	Water	0°C	80 Kcal/kg	fl. 0.0007/kg
$Na_2S_2O_3.5H_2O$	Natriumthiosulfat Pentahydrat	49°C	50 „	0.40 „
$C_{16}H_{32}O_2$	Palmitic acid	62°C	39 „	13.00 „
$C_{10}H_8$	Naphthalene	80°C	35 „	7.50 „
$C_{10}H_8O$	Naphthol	95°C	39 „	37.50 „
$C_4H_4O_3$	Soccinic Anhydride	119°C	49 „	28.00 „

In the above scheme it becomes clear that reasonably useful materials are available, but the most attractive ones are extremely expensive. The prices indicated for the 'organic compounds' (C-H- products) are for pure and stable products but the requirements as to their storage possibilities could be much lower, which might have its effect on these prices.

Financial considerations

Investment costs

A very rough comparison of the parts of a conventional versus total energy heat pump installation is opposite:

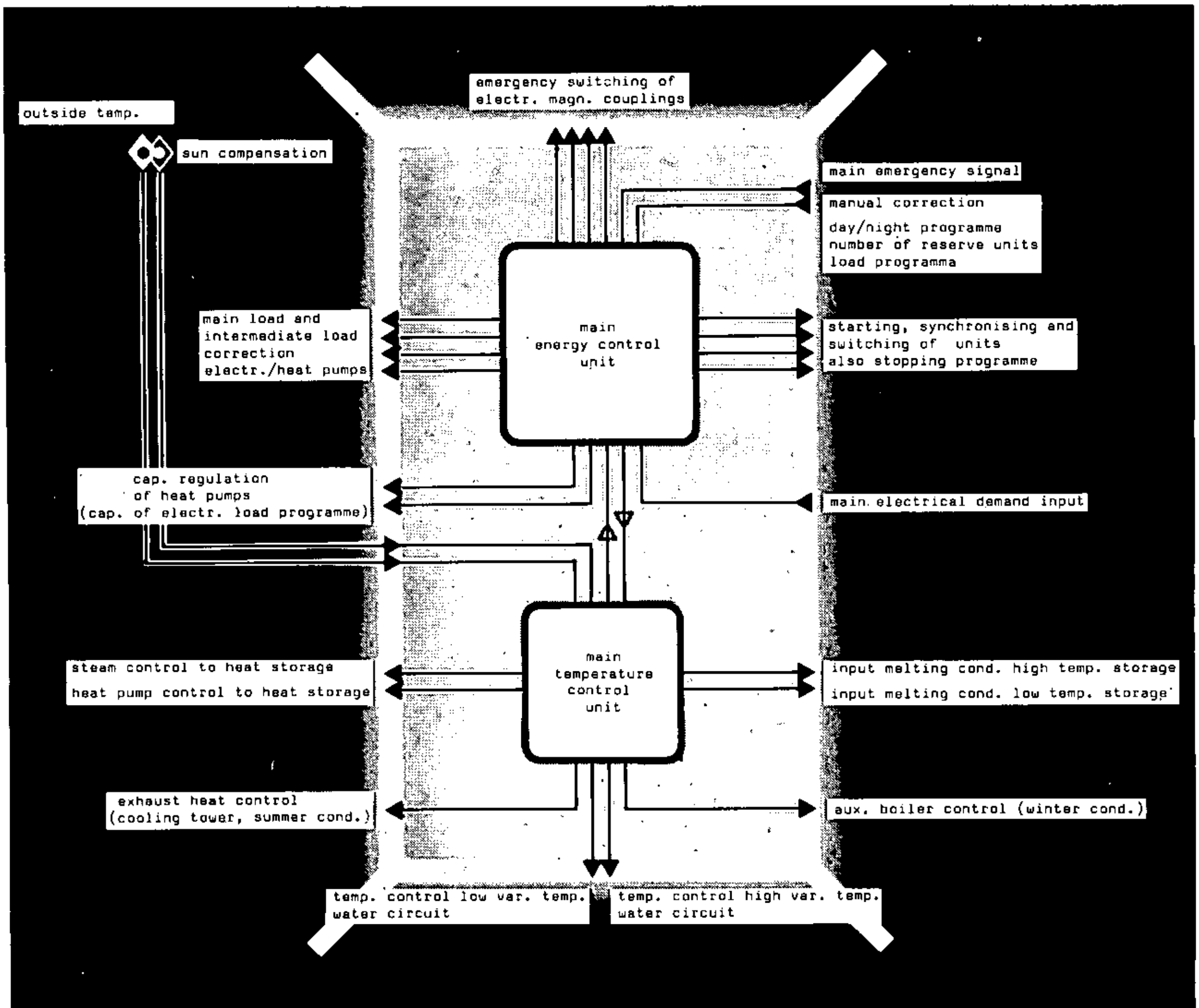
TE heat pumps

Electricity supply	generators voltage compensator (if necessary)
Heat supply	dual fuel engine (or gas turbine) waste heat boilers auxiliary boilers (if necessary)
Cooling	heat pumps

Conventional system

Electricity supply	high voltage transformer emergency generator no-break sets
Heat supply	boilers
Cooling	refrigeration compressors (or absolute cooling machine)

It is very difficult to make any exact financial comparison. In this respect it is perhaps interesting to quote some figures from the above mentioned investigation in Holland, in relation to the capacity of emergency generators. The capacity of these generators has increased from about 1.0 kVA/bed in 1966 to about 1.85 kVA/bed in 1974. The most modern hospitals in particular have very high capacities of 3.8 to 4.3 kVA/bed. The three hospitals which have been provided with total (selective) energy installations have capacities of 3.44, 5.47 and 5.33 kVA/bed respectively. In summing up all these figures we come to the conclusion that at this moment a total energy installation for a general hospital requires twice the capacity of normal emergency generators. As mentioned before 'no-break' installations make up an important part of investment costs. Furthermore the costs of heat pumps very much depend on whether serial-made compressors are used, as explained previously. In my opinion there is not much of a difference between modern conventional installations, with a high electrical emergency capacity and a reasonable number of no-break sets, and a total energy heat pump system as far as the basic parts are concerned. The latter system, however, needs a very efficient control system which must perhaps be computerised, in order to keep the installation continuously in balance. This means an increase in cost, however it also means a reliable performance, as well as maximum savings in fuel and perhaps personnel costs, which are directly dependent on the performance of the control system. Starting point for the design of the installation must be an automatic working system which also



example of main control system for total-energy heat pump installation fig. 8

includes: starting, stopping and synchronising procedures for the generators. For an idea of the control (regulating) system, a basic diagram is given in *Figure 8*. Unfortunately I have no idea of the investment costs involved in such a complete control system.

Running costs

The most important item of running costs is that of energy. It would be very interesting to know how much energy could be saved this way as compared with conventional systems. Rough estimations of energy consumption to provide air-conditioned hospitals have taught that the ratio of consumption of electricity to heating to cooling is about: 1 : 3 : 3/4. Proceeding from these figures a comparison of consumptions will be calculated with the help of the schematic *Figure 9*. When seen from the primary energy point of view, energy saved will amount to 42% of all energy used in those cases where a conventional system has been installed. This is of course also of general interest, since it means a lower degree of pollution of the atmosphere by heat and gases. If however we wish to compare costs, we must realise that in comparison electricity costs are also much higher than the costs of heating and cooling. To make such a comparison possible we must introduce the figures:

calorific value of natural gas=7560 Kcal/kg.
boiler efficiency=80%.
1 kWh=860 Kcal/kg.
rates in 1975 (all-in) gas=fl. 0.17 m^3 elec.=fl. 0.13 kWh.

The electricity used in a conventional system has to be multiplied by:

$$\frac{7560 \times 0.8}{860} \times \frac{13}{17} = 5.38$$

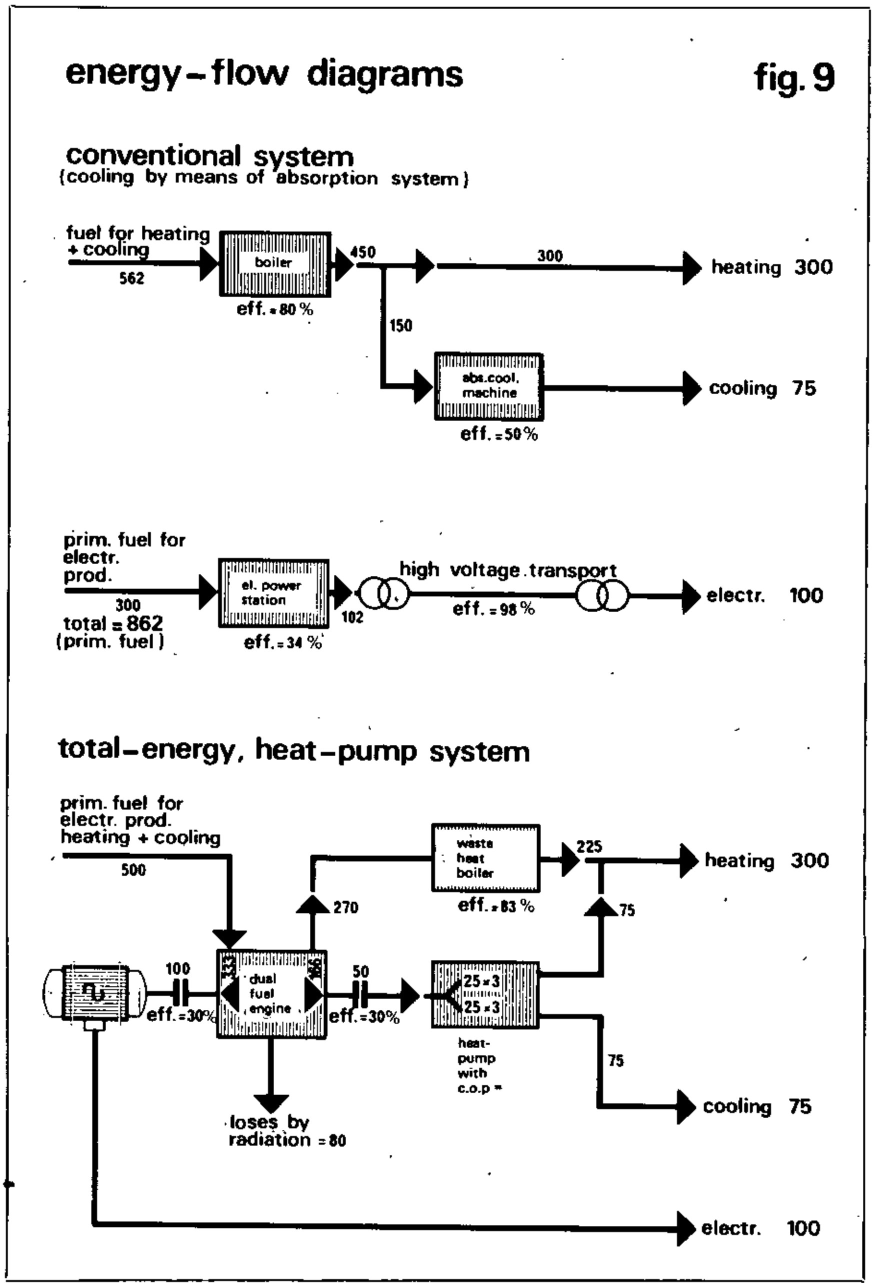
In this case the energy costs for the conventional system will be: 5.38 × 100 + 562 = 1100 (see *Figure 9*). Consequently the saving in energy costs will be no less than 54% of the energy costs where a conventional system is installed.

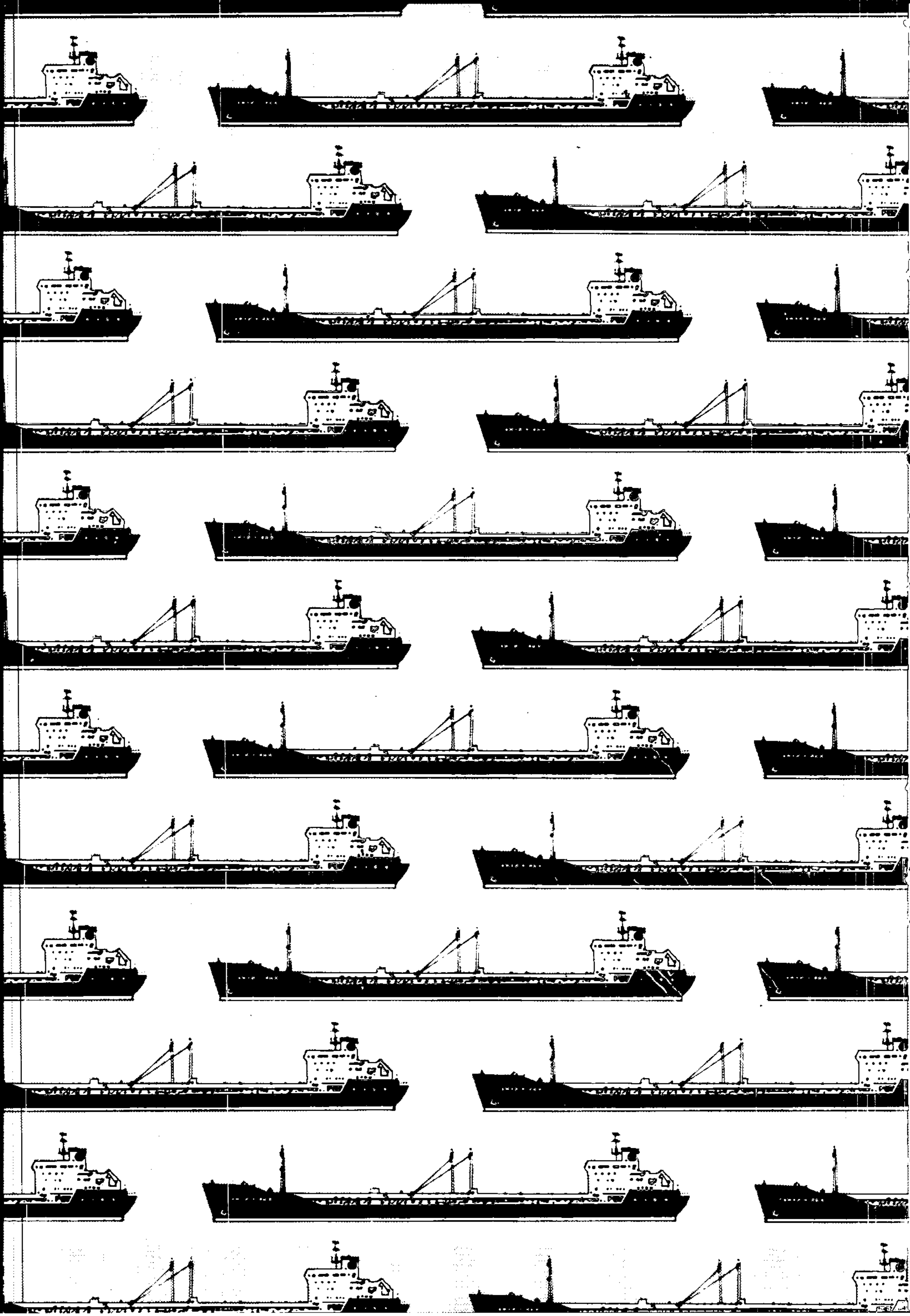
In the Netherlands the costs of energy, which means electricity and natural gas for many modern hospitals with air-conditioning, are about: fl. 8 patient/day. For a 600 bed hospital for example, this means energy costs of no less than fl. 8 × 600 × 0.9 × 365 = fl. 1,576,800/year, about £300,000/year. If the above mentioned savings are possible this means an amount of approximately fl. 850,000 a year or about £170,000 a year. These figures which appear to be somewhat optimistic, actually are such that undoubtedly many investments could be made with the certainty that they would pay for themselves within a short period.

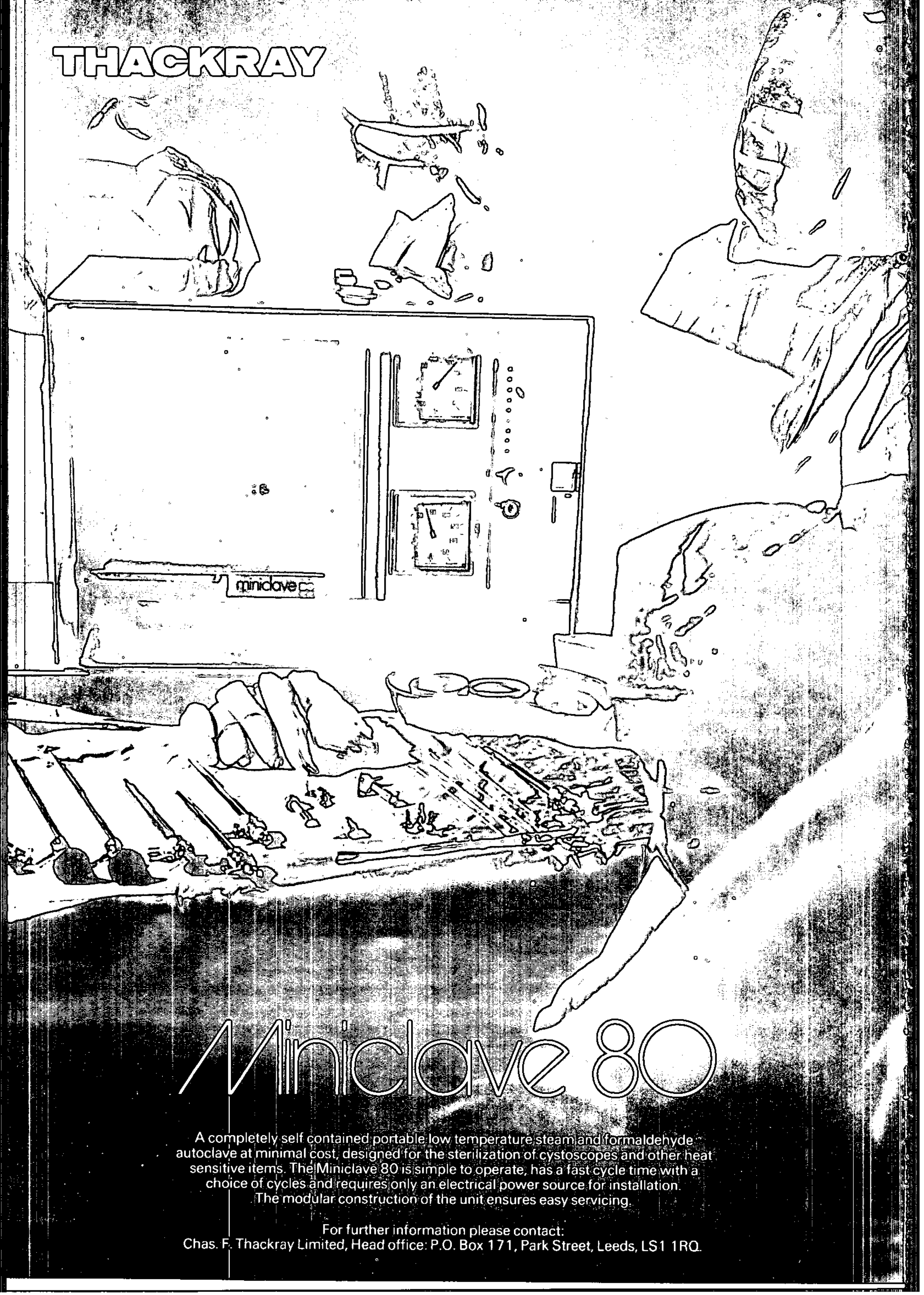
In the total design, however, heat consumption, even in summer time, such as kitchen, laundry, sterilisation, warm water hydrotherapy, water distillation etc., is supposed to be such that waste or surplus heat will be utilised as much as possible. It will be possible to introduce absorption cooling too, but in my opinion this is not very efficient, because: investments will be influenced disadvantageously; absorption machines operate with low efficiency rates.

For application in tropical areas however the introduction of a small low pressure steam turbine for driving cooling compressors seems to be more attractive than the application of absorption cooling for the utilisation of surplus heat or low pressure steam from the waste heat boiler.

With these figures in mind the question arises whether the efficiencies and other data used for the calculation are to be considered realistic. To answer this question, one has to keep in mind that the efficiency of the installation depends on the efficiency of the total energy part of the



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plant and also on the CoP of the heat pump. Of the total energy side, in my opinion, the efficiency rates of 30% and 45% (total 75%) could easily be reached if heat storage is used, because the installation will operate at full capacity when the control-system is working perfectly and continuously. For the CoP of the heat pump system a simple calculation will be made to decide whether a CoP of 3 could be obtained with the installation as shown in the calculation. The following conditions are required:

the necessary outgoing water temperature = 90°C (winter);

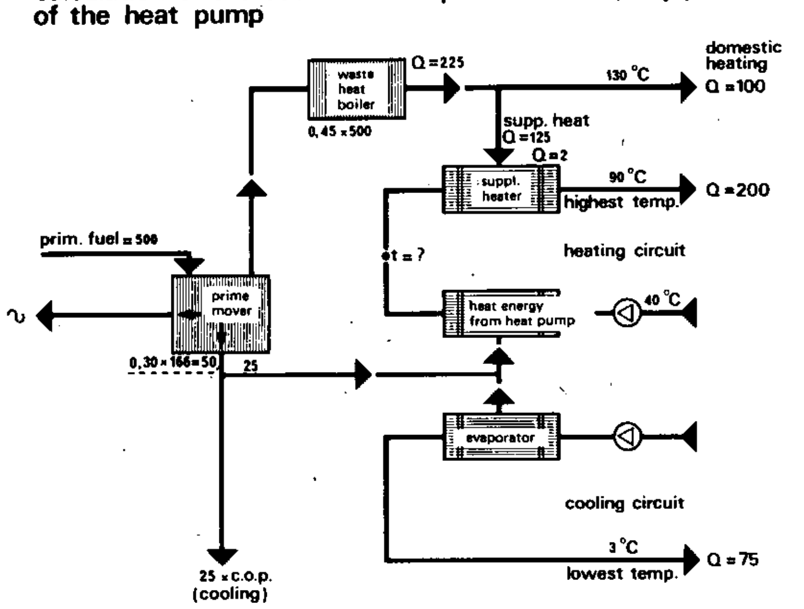
the return water temperature of the high water temperature water system = 40°C;

the temperature of the means from which waste heat is taken is unknown.

Care has to be taken in those cases where waste heat is withdrawn from the exhaust air. This air also contains, apart from the heat-energy drawn from the installation, heat energy which it derives from people, apparatus and lighting. The temperature of the air varies from about 23 to 25°C. This temperature of course cannot be considered as a basically constant temperature when outside air or water from a river are used as a heat source. The exhaust air of the air-conditioning will drop in temperature when taking heat energy for regeneration purposes. In such cases we must introduce the average temperature, and this could safely be estimated to be 10°C. When heat is obtained from sewage water systems, the average temperature of this water may be expected to be about 10°C. With *Figures 3* and *9* to represent a basic situation in which to find the CoP, we are able to introduce the abovementioned figures and we can produce *Figure 10.*

fig. 10

calculation of the coefficient of performance (c.o.p.) of the heat pump



In this figure we assume the situation to be such that the ratio of heat delivery for heating (air-conditioning) to the heat supply for domestic services such as kitchen, laundry, humidification, sterilisation etc. will be as 2 to 1. Considering that the heat delivery is proportional to the differences in temperature we can produce the simple equation of:

$Q1 : Q2 = (t - 40) : (90 - t)$, where $Q1 = 25 \times CoP$ and $Q2 = 125$.

For the CoP we can write:

$$\frac{273 + t}{(273 + t) - (273 + 10)} \times 0.5.$$

Filling in all these figures we can produce the following quadratic equation:

$$\frac{273 + t}{(273 + t) - (273 + 10)} \, 0.5 \times 25 : 125 = (t - 40) : (90 - t).$$

The temperature t will be found to be = 60°C.

Introduction of this temperature to find the CoP will prove that the CoP = 3.325. In most cases we may expect that the CoP will be higher, because the outgoing temperature of 85 to 90°C will only be necessary in cold winter periods. It is therefore most important to drop the temperature when the climate conditions permit it. This means using a highly variable temperature water circuit.

On the low temperature side a CoP of 3 to 4 is not uncommon. In the system as described in this paper the CoP value of 3 is chosen and this is on the safe side, also taking into account that the lowest temperature will only be required in summer. In this respect it is also very advisable to raise the temperature of the low variable temperature water circuit if circumstances allow this. With this simple calculation it has been proved that the heat pump which is a part of the total installation can easily reach a CoP of 3 when possibilities of heat regeneration have been introduced into the system.

The total energy heat pump system and the future

The electricity supply

The generation of electricity by one's own equipment provides the opportunity to introduce new ideas about voltage and frequency. It is well known that the production of light is more economic when a frequency of 400 Hz is used instead of 50 Hz. Also the starting devices, should TL lighting be used, will be smaller in size and consequently cheaper. Perhaps it would be interesting to watch for further developments so as to consider whether two electricity systems instead of one, perhaps both with separate generators, should be installed.

The fuel supply

It will be obvious that the total energy heat pump system consumes much less fuel than any other energy supplying system. Besides the high thermal efficiency which can be obtained, a great portion of heat is taken from other means, thus resulting in a negative consumption of fuel, whereas the atmosphere is in no way influenced by this type of heat supply. However a certain amount of fuel is required to keep the system in operation, and this fuel (gas or oil) is going to be in scant supply. Answering the question about the future roles of these systems, attention should be given to the following facts:

Nuclear power will come more and more to the fore. Electricity supply is the most usual method of transforming nuclear energy, however this transformation has been attended by low thermal efficiency rates until now, thus burdening the atmosphere with waste heat. Also the long supply lines of electricity sometimes give problems, especially in densely populated areas.

In recent times special attention has been given to the development of oxygen production by means of nuclear energy. This would be applicable in those cases where the possibilities are being considered of situating nuclear power stations outside populated areas — for instance on artificial islands in the North Sea. The new principle which is being developed and which may possibly be very useful to the new reactor type, is the so-called 'Zdansky-Lonza' process. In applying this method, the power that is needed for oxygen compression in order to make it suitable for transportation, could be saved. This process can attain an efficiency of 80%. However, electrical energy is necessary for this electrolosis-process, whereas the overall efficiency will rise from 27 to 35%. Despite this low efficiency, production of oxygen could take place at those periods when the electricity demand is low, i.e. during the so-called silent hours. Estimates of the silent hours have shown that about 37% is available and that besides about 27% of reserve power could at times be used for this purpose, making about 50% of this power available for oxygen production in the electrical power stations.

Another activity in this development is the process whereby chemical reactions are used at high temperatures in stages. The new type He-cooled nuclear reactor could also be used for this purpose. The expected efficiency to be reached with this system is estimated at 55%.

The influence of transport costs will not be negligible with regard to the total cost of oxygen as general fuel.

Another activity in the field of oxygen production comes from investigations in bio-chemical laboratories. The basic principle of the production of oxygen by means of micro-organisms lies in the use of albumen, like the enzym hydrogenase which acts as a catalyst with the aid of electrons.

In summing up all activities in the field of the production of oxygen, we may expect that oxygen will play an important part in the fuel supply of the future not despite nuclear power, but rather as a result of the growing use of nuclear energy.

The prime movers

Starting from the above-mentioned activities, it will doubtless be possible to use oxygen in combustion engines. Perhaps some alterations on the fuel supply side will be necessary, but they will not be of too great an importance. The dual fuel engine will probably be the most useful engine for this purpose. Apart from piston engines, the gas turbine could also be very useful as prime mover. At the moment a prime mover of this kind seems to be attractive only by its reasonably high power demands (above 1000 kW), mainly based on economical considerations. An advantage might be that the gas-turbine is more adapted to the use of alternate fuels such as heavy oil and gas obtained from coal. It will also be greatly interesting to follow the developments of the introduction of the so-called 'hot air engine' (Philips research). This engine is reported to reach a thermal efficiency of 40%. Another advantage that has come to light is that it has the same capacity as the gas-turbine, in that it runs on all kinds of fuel.

Summary

Energy consumption in modern hospitals has risen to a considerable extent during the past ten years. Efficient energy use is going to be important for economic reasons as well as for reasons of general environmental interest, e.g. pollution of the atmosphere.

Application of total energy and heat pump installations can both play an important part in the attempt to save energy;

Combination of total energy and the heat pump process could enlarge the specific advantages to such an extent that energy savings of 42% become possible, even obtaining savings in the cost of energy up to 54% compared with conventional systems;

The heat pump's working on the low-end heating side is of importance, not only to the CoP of the heat pump but also with regard to cost, for serially produced heat pumps may be used;

Heat pumps are very useful for recovery purposes. This could be of importance in hospitals because of the relatively high amount of waste heat in exhaust air and sewage water;

Introduction of heat storage systems in those cases where the total energy heat pump system has been taken into consideration, will give special advantages because of the flexibility of operation, which can reduce costs of investment in engines and heat pumps, and which provides for emergency situations. It also promotes the efficient operation of the installation since by using a good working control system, the prime movers will be able to run almost at full capacity, which gives high efficiency results;

Heat pumps can supply heating or cooling energy alternatively or even at the same time. No separate cooling machines are necessary. The cooling water system can also be used for purposes of heat recovery;

By using special couplings between prime-mover and heat-pump, or by using short circuit valves at the heat pumps, in emergencies the heat pump can be switched off temporarily. Power will become available immediately for electricity supply. The heat storage system can temporarily supply heating or cooling energy. This arrangement makes the installation very reliable as far as the electricity supply is concerned. Additional connections to the local electricity board are not therefore, considered necessary;

This installation does not require emergency generators or no-break sets. Some reserve power must however be included in the installation, but this can be of small capacity because of the flexibility of the total concept of the installation. The only important investment in comparison with the conventional system is the control system. Energy will be saved to such an extent that these investment costs may be refunded within a short period;

The total energy/heat pump combination could also play an important part in the future. If the prime movers are chosen with care, the use of oxygen as a primary fuel, which is becoming more and more interesting, will be quite possible.

Hospital Engineeers invariably encounter various types of washing machines and other allied equipment performing specific duties in every hospital. Most of us have, however, concerned ourselves with their functional, preventive maintenance or breakdown repair aspects without paying any attention to the actual process details and the cleaning mechanism. This article investigates a possible mathematical presentation of the movement of linen in 'D' pocket type washing machines having horizontally rotating cylinder with a partition dividing it into two pockets.

The Trajectory of Garments in Washing Machines

J. SINGH BINDRA BTech ChemEng MS ChemEng

The tumbling action in the cylinder consists of four parts depending upon the actual state of the load. Referring to *Figure 1*, the following sequence of movements is observed:

(i) The load is lifted by the partition;
(ii) the load slides on the partition;
(iii) the load falls inside the cylinder;
(iv) the load hits the peripheral sheet of the cylinder with an impact.

During lifting water drips out of the load, during sliding and falling nothing appreciable happens to the water content, but during impact additional water is forced out of the load.

The movement of load, having constant dryweight, has characteristics similar to those of fluid. Load movement, therefore, resembles that of a particle lifted by partition. The radial movement is assumed to be negligible and the interaction between the particles is overlooked.

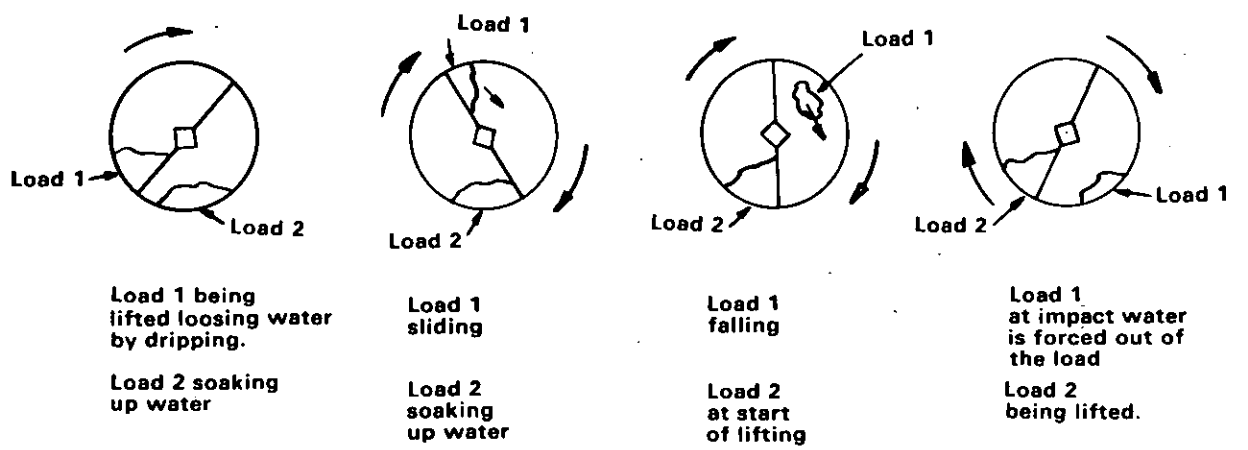
Frictionless model

This model is based on assumption that the load acts as a frictionless solid particle. At any angle Θ the gravitational force opposes centrifugal force (see *Figure 2*). The co-ordinate system is radial, the outward direction being positive, and the angle is measured from the horizontal axis. At the critical angle Θc the centrifugal force for the initial radius will equal gravitational force.

$$Fc = M r w^2 = F gr = Fg \sin \Theta = Mg \sin \Theta$$

$$\text{At critical angle } \sin \Theta c = \frac{r\omega^2}{g} \quad - - - (1)$$

Figure 1: Movement of load



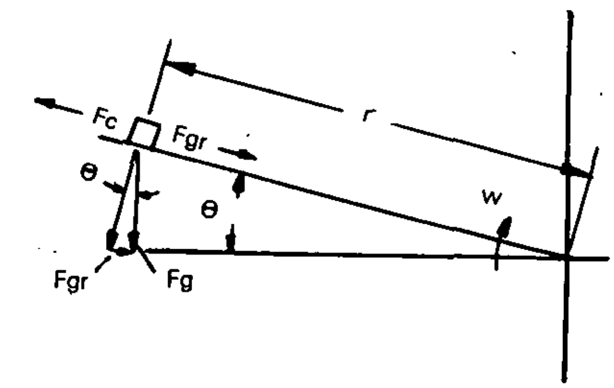


Figure 2: Force balance on load

After θc the gravitation component continues to increase and the particle accelerates towards the centre of rotation. The equation of motion is represented as

$$\Sigma F = M\frac{d^2r}{dt^2} = F_c - F_{gr} = M r w^2 - Mg \operatorname{Sin}(\theta c + wt)$$

$$\text{Or, } \frac{d^2r}{dt^2} - w^2 r = g \operatorname{Sin}(\theta c + wt) - - - (2)$$

$$\theta c \leqslant \theta c + wt \leqslant \beta \text{ and } ro < r < o$$

Where β is the angle where the load separates from the partition.

This is a special case of the mechanical vibration system represented by

$$m\frac{d^2 x}{dt^2} + C\frac{dx}{dt} + K X = F(t)$$

Equation (2) represents a forced, undamped vibration system. The general solution of equation (2) is:

$$r = A e^{-wt} + B e^{wt} + \frac{g}{2w^2} \operatorname{Sin}(\theta c + wt) - - (3)$$

Initial conditions:

$$t = o,\ r = r_o \text{ and } \frac{dr}{dt} = o$$

Substitution of initial conditions in (3) yields

$$A = \frac{ro}{2} - \frac{g}{4w^2}(\operatorname{Sin}\theta c - \operatorname{Cos}\theta c) - - - (4)$$

$$B = \frac{r^o}{2} - \frac{g}{4w^2}(\operatorname{Cos}\theta c + \operatorname{Sin}\theta c) - - - (5)$$

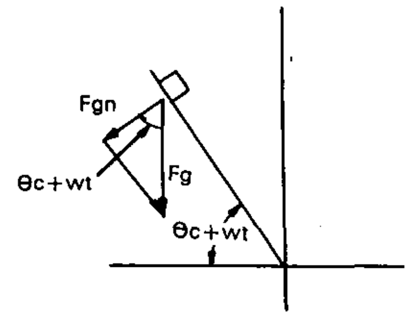


Figure 3: Sliding of load

Analysis of normal force on the partition indicates that at the position where the normal force reduces to zero, sliding of the load finishes and the free-fall begins. From *Figure 3*, it is obvious that the gravitational force normal to the partition decreases as the angle increases. Mathematically it can be represented as:

$$F_{gn} = -F_g \operatorname{Cos}(\theta c + wt) \qquad = -mg \operatorname{Cos}(\theta c + wt)$$

During sliding the radius of load is decreasing while the speed of rotation remains constant. This results in decrease in the reaction force of the partition on the load. This phenomenon is termed as 'Corriolis' effect.

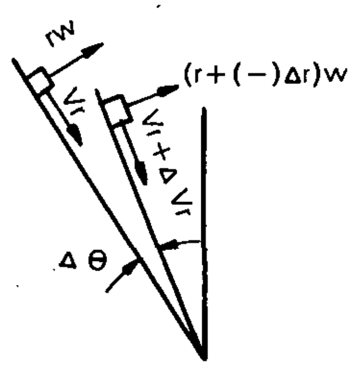


Figure 4: Acceleration normal to the partition

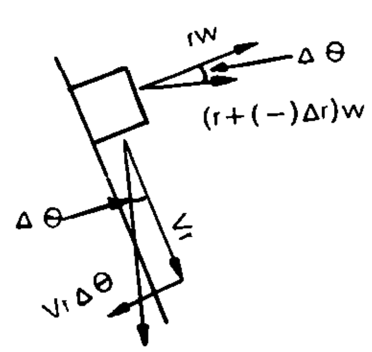


Figure 5: Free fall of load

Referring to *Figures 4 and 5*, acceleration normal to the partition is represented as

$$\Sigma \frac{\Delta V}{\Delta t} = \frac{(r + \Delta r) w - rw}{\Delta t} + \frac{Vr \Delta \Theta}{\Delta t}$$

$$\frac{\Delta r}{\Delta t} w + Vr \frac{\Delta \Theta}{\Delta t}$$

$$= 2 w \frac{\Delta r}{\Delta t}$$

$= 2$ w Vr (at the limit)

(Here $Vr = \frac{\Delta r}{\Delta t}, \frac{\Delta \Theta}{\Delta t} = w$)

The instant when the gravitational force equals the partition reaction the load starts to fall freely and sliding stops. At this point

$$m \Sigma \frac{\Delta v}{\Delta t} = m\, 2\, w\, Vr = - m\, g \cos(\Theta c + wt)$$

$$\text{Or } 2 w \frac{dr}{dt} = - g \cos(\Theta c + wt) \text{ - - - - - - - - (6)}$$

Substitution of $\frac{dr}{dt}$ from (3) in (6) yields

$$A e^{-wt} - B e^{wt} = \frac{g}{w^2} \cos(\Theta c + wt) \text{ - - - - - - (7)}$$

Graphical presentation

The movement of load, assuming frictionless model, for a washing machine at 21 inch radius rotating at 28 rpm can be plotted with the following equations and data.

Basic Equations:

$$r = A e^{-wt} + B e^{wt} + C \sin(\Theta c + wt)$$

$$A e^{-wt} - B e^{wt} = 2 C \cos(\Theta c + wt)$$

Equation for constants:

$\Theta c = \arcsin\ (w^2 ro/g)$

$$A = \frac{ro}{2} - \frac{g}{4 w^2}(\sin \Theta c - \cos \Theta c)$$

$$B = \frac{ro}{2} - \frac{g}{4 w^2}(\sin \Theta c + \cos \Theta c)$$

$C = g/2w^2$

Constants:

$g = 32.2$ ft/sec^2

$w = 28$ rpm $= 2.93$ rad/sec $= 168$ deg/sec

Parameter:

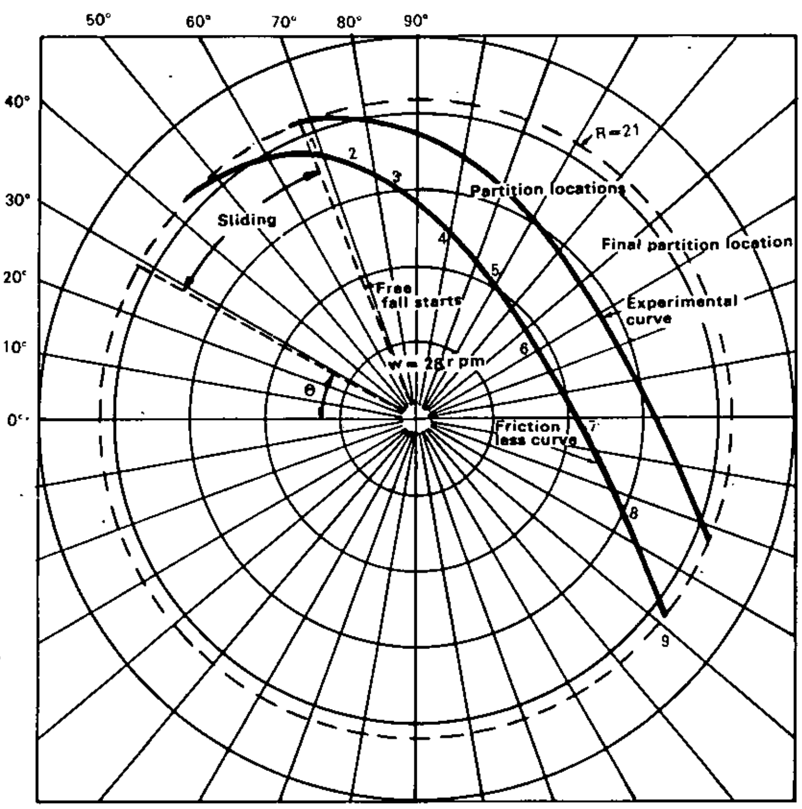
$r_o = 21$

Variable:

$wt = 0, 0.2, 0.4, 0.6, 0.62, 0.64, 0.66, 0.68, 0.70$

The path as per the model is plotted as shown in *Figure 6*.

Figure 6: Trajectory of load



Experimental

To verify the calculations of the movement of a particle at 21 inch radius on the partition of a washing machine rotating at 28 revolutions per minute, an experiment was conducted. Lights were wired to the partition and to the particle. One light indicated the path of the partition while the second neon light went off when the particle left the partition. Other lights were directed onto the particle to illuminate its trajectory.

The experiment was conducted at night with all unnecessary illumination switched off. A camera with the lens (focal length of 2.8) wide open was placed in front of the machine. The film used was Kodak Tri X, speed ASA 400. To fill in the background an electronic flash was operated from a distance of 25 feet towards the machine.

Data was collected from the photography and plotted on polar co-ordinates. The path of light was made concentric with the axis on polar paper and a reference perpendicular axis was selected. The photograph was then traced on the polar paper and enlarged as shown in *Figure 6*.

Results

The results indicate that friction is much larger than expected, but the neon light is observed to go out at about the same place. It means that the free fall starts at the same angle in experiment as well as in the model. However, experiment indicates that there was little or no sliding.

Overlapping of several negatives indicate slightly different paths. However, the point at which the load hits the side of the cylinder is almost the same.

Conclusions and recommendations

From the experiment it is obvious that the frictionless model does not accurately represent the movement of garments. Friction has been observed to be much larger. The frictionless model is useful only to the extent of the determination of the angle where the load starts falling freely, or the location where it would hit the side of the cylinder. These are of some help in the design of a washing machine.

A new model with appropriate friction function may be investigated for further insight into the phenomenon.

Mr. Soheili is the chief engineer of the Iranian National Blood Transfusion Service, and also practices as a consulting engineer for building services in Tehran.

In this article he discusses the practicalities of freezing and storing blood.

Cold Storage for the Preservation of Plasma

M. SOHEILI

Blood transfusion – the application of refrigeration

Since 1820 when ice was first artificially made on an experimental basis, the science of refrigeration and its applications has become very important, widely developed, and highly specialised. Application of refrigeration in the medical profession is increasing daily, particularly in the preservation of certain vital products. During the past thirty years great advances have been made in the field of blood component production and it is now possible to produce the following components routinely:

WHOLE BLOOD

Cellular Components
Packed Red Cells
Concentrated Leukocytes
Platelets

Plasma Components
Single Donor plasma
Coagulation Factors
Fibrinogen
Albumin
Immunoglobulins

Storage of red cells above 0°C

Whole blood with anticoagulant is stored at a temperature in the range of 2-6°C, usually at 4°C. At this temperature, the rate of cell metabolism, i.e. glycolysis (glucose breakdown), is some forty times slower than at 37°C (*M. M. Strumia, 1954, N. C. Hughes-Jones, P. L. Mollison and M. A. Robinson, 1957*) and hence the survival rate is longer.

Despite this reduction in cellular metabolic activity, there is still a progressive loss of red cell viability. For example, after 21 days in acid-citrate dextrose, which is the most widely used anticoagulant, the viability of red cells in whole blood is approximately 81%, while in packed cells (where the supernatant plasma has been removed) it is 72% (*C. E. Shields, 1969*). The reasons why blood is normally stored at 4°C are not immediately obvious. It is probably a good compromise between a temperature which gives good preservation and one which is also safely above the freezing point of blood (*P. L. Mollison, 1972*). Thus, blood is kept as cold as possible without allowing it to freeze.

Storage of red cells in the frozen state

If red cells are stored at less than —45°C, their viability is maintained for a very long period. To date, however, no simple method has yet been devised for storage at such a low temperature. The main problem is that some cryoprotective must be added to the red cells to protect them from damage during the freezing and thawing. Glycerol has proven to be effective and non-toxic. It is a permeating substance, however, and must be removed from the cells before transfusion. If not removed, it will cause haemolysis in the patient through an osmotic effect. When a solution freezes, pure ice forms and remaining liquid becomes hypertonic. *J. E. Lovelock (1953)* showed that many of the damaging effects of freezing upon tissues are those resulting from exposure of the tissues to a hypertonic solution, followed by an exposure to an isotonic solution. If glycerol is added to red blood cells, they can be frozen and thawed without damage (*C. Polge et al, 1949*). The effect of glycerol is probably due to the fact that it limits ice formation and provides a liquid phase in which salts are distributed as cooling proceeds, such that hypertonicity is avoided (*J. E. Lovelock, 1953*).

There are two main refrigeration techniques employed for freezing red blood cells: the high glycerol — slow freeze, to storage at —65°C to —85°C by mechanical method (40% glycerol concentration (*J. L. Tullis et al, 1970* and *H. T. Merryman, 1972*) of 47% glycerol concentration (*C. E. Huggins, 1970*) and the low glycerol — rapid freeze to storage at —150°C to —195°C by liquid nitrogen technique (17.5% glycerol concentration) (*H. W. Krijnen, 1964* and *T. W. G. Rowe, 1968*) or 14% glycerol concentration (*O. Akerblom* and *C. F. Hogman, 1974*). The cost of storing red blood cells by liquid nitrogen is estimated to be five times more expensive than mechanical refrigeration (*L. Lukmskyj* and *Chang Ling Lee, 1974*).

Platelets

Platelets are extremely fragile and do not remain viable for long periods of time. Blood stored in acid-citrate dextrose for even 24 hours at 4°C is a poor source of viable platelets (*D. F. Jackson et al, 1956*). Storage of platelets at 22°C gives better results than at 4°C. No method has yet been discovered which freezes platelets without excessive damage.

Leukocytes

In acid-citrate dextrose blood, kept at 4°C, the leukocytes (white blood cells) survive fairly well for about two days. By the end of 96 hours all antibacterial activity is lost (*J. McCullough et al, 1969*).

Plasma

For optimum yields of plasma component, the plasma should be separated from blood cells as quickly as possible following collection and then stored at less than −40°C until required for fractionation.

From the above summarised references, the role of cryogenic engineering in blood transfusion becomes quite obvious. It is apparent that refrigeration in the storage of blood and blood products is gaining remarkable and widespread importance.

One of the major applications of refrigeration in the blood transfusion services is the cold storage of plasma as a derivative of blood. Plasma makes up about 55% of the volume of blood, and transports the water and nutrients obtained from food to all the cells of the body. Plasma also carries minerals and hormones essential to normal body development, and various waste products to kidneys for excretion. Plasma also contains a number of proteins and other substances vital in maintaining health. Plasma is usually preserved in the cold stores at −40°C to −70°C for long periods before being used to treat specific disorders and illnesses.

There are many reputable manufacturers who mass produce rather decorative standard refrigerators with sensitive thermostats, alarm systems, recording thermometers, and other controls specified by national health institutions. These refrigerators are in widespread use in blood banks and hospitals for preservation of plasma and other blood components.

In the field of larger size plasma cold stores, which are specifically required by large blood transfusion services in major metropolitan areas, a refrigeration engineer may become involved in cooling load estimation, selection of equipments and controls, etc.

In this article general information about blood will be given, and the means provided by refrigeration technology for its preservation will be briefly explained. Though the principle of refrigeration for designing a cold store is almost routine, some additional bases for its design, in reference to storing plasma, will be outlined.

Air temperature, motion, and humidity

In analysing the complete subject of environmental conditions for preservation of plasma, consideration should given to two basic questions:

1. What is the correct temperature for storage?
2. For what period can the product be stored?

For storage of large quantities of plasma −40°C (−40°F) is the temperature of choice. This is because in temperatures above −40°C protein losses during storage become too large to be acceptable, and below this temperature the cost of refrigeration makes the process economically unfavourable.

For long term storage of plasma on a small scale in the laboratory, −70°C (−94°F) is desirable. Losses of viable protein are minimal at this temperature, although, obviously it is not economically feasible for large bulk storage.

If the optimum inside design temperature of a freeze chamber is determined to be −45°C (−49°F) it is believed that the fluctuation of plus or minus 5°C in the temperature range of −40°C to −50°C is not critical. More investigation must be carried out regarding temperature fluctuation in the course of storage. At present, little study has been given to the method of freezing of plasma for bulk storage i.e. rate of freezing. However, it would seem that from available information, freezing as rapidly as possible is preferable, to minimise protein denaturation.

The turn over time of plasma cold storage is rather vague because of variables in blood donations. For example, blood donations procured in the Moslem countries is noticeably reduced in the fasting month of Ramadan. The variation may also have no sensible and logical cause. Despite this variation, the manufacturing of plasma products has to be continued. Hence, the storage period of plasma in a main blood transfusion centre could either be short term or long term. Though there is no hard and fast rule for plasma storage, the maximum period of plasma storage at the above-mentioned temperatures is about six months.

A relationship between temperature and the length of time for storage must be established, although little is known or universally accepted about this relationship. The writer has not found any literature recommending temperature and relative periods of storage.

Though the stagnant air is not really deleterious for frozen plasma, air velocity is preferred to be just sufficient to provide adequate air circulation in the freeze chamber, to assure uniform cooling, at − 40°C to − 50°C.

On the contrary, in the cold room, air motion should be as high as 1.27 m/s (250 ft/min). This would assist the melting of frozen plasma, when + 4°C cold room is used for thawing.

Generally inside air in a plasma cold store is almost saturated; but as plasma is always kept in plastic bags or some kind of closed containers, space relative humidity requires no control.

Plasma cold storage construction

Plasma cold storage consists of two walk-in compartments. The first compartment is a cold room equipped with one refrigeration system, with one cooling unit located in the room to maintain air temperature at + 4°C (+ 39°F). While this room serves for the purpose of thawing plasma, it also prevents direct flow of ambient air current into the freeze chamber.

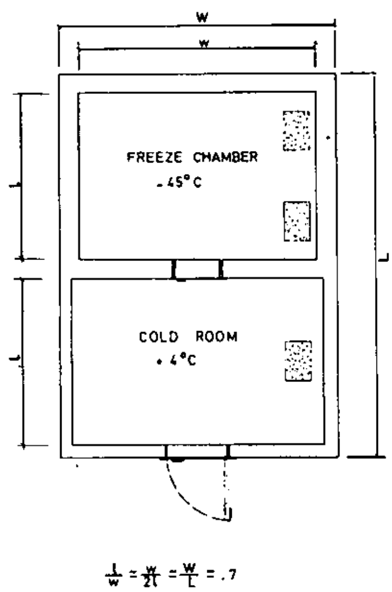
The utilisable surface of the entrance cold room is preferentially equal to the utilisable surface of the freeze chamber.

The second compartment is the freeze chamber, equipped with two refrigeration systems, each one with full load capacity. The systems have two compressors, two condensors, etc. This provides security in the event of mechanical failure of one system. Though a single system is acting as a stand-by, if it is necessary at the start, quicker freezing is achieved when the two systems operate coincidentally. Each system has two or more cooling units to maintain the temperature of the freeze chamber at about − 45°C (− 49°F).

The size of plasma cold storage is designed according to present requirements, anticipated growth and available space. In *Figure 1* some dimensional ratios are suggested to achieve a good configuration, and to offer optimum storage possibilities for bulk storage rooms.

Though the size of plasma cold storage is not standardised, it is convenient to have the doors of a standard size to enable them to fit into the different cold storages. For example when the interior height is 200 cm (6 feet 7 inches), door free opening of cold entrance room is suggested to be 180 cm × 76 cm (5 feet 11 inches × 2 feet 6 inches) and door free opening of the freeze chamber 160 cm × 71 cm (5 feet 3 inches × 2 feet 4 inches).

Figure 1



The main factor contributing directly to obtaining and maintaining the required temperature is the insulation material. In many countries cork is still available, but throughout the world it is beginning to be replaced by materials such as glass fibre, polystyrene, polyurethane, etc. However a plasma cold storage is usually constructed of board on both sides of studs. The warm side is properly vapour sealed and the whole storage is covered inside and outside by sheets of stainless steel or bright galvanised steel. The insulating material of a freeze chamber and cold room should have a relative insulating effect of 30 cm (12 inches) and 10 cm (4 inches) of good quality cork or cork equivalent, respectively.

Refrigeration load and capacity estimation

When the amount of plasma to be preserved is determined, the load estimation follows six steps, and selection of correct size and capacity of equipment depends on intelligent estimate of the magnitude of refrigeration load and capacity.

At first, the special programme of the Blood Transfusion Service should be carefully studied. Then, as mentioned previously, the volume of the cold storage is determined in accordance with the present requirement and probable future expansion of that particular blood transfusion centre.

Load estimation is calculated by simple arithmetic, the only complexity may lie in the product-load. Although the growth of published references for cold storage of numerous products is astonishing, the lack of sufficient information on thermal properties of blood and blood components in the refrigeration guides and data books, would lead the engineers to practise rule of thumb methods quite frequently. The familiarised steps of load estimation are listed below with some related information.

Step 1 — Transmission load

Plasma cold storages are normally placed in a closed and air conditioned environment, and it must be protected against any source of heat, especially radiation.

If the summer air temperature of the conditioned space is taken as 24°C (75.2°F), the temperature difference between outside air and the inside of the freezing chamber shall be 69°C (124.2°F), and Δ T for the cold room shall be 20°C (36°F). Considering BS code of practice recommendation, and the temperature differences, the overall heat transmission coefficient for the walls of freeze chamber should not be more than 0.153 W/m² °C (0.132 Kcal/m²h °C — 0.027 Btu/h ft² °F) and U value for the walls of cold room could be about 0.380 W/m² °C — 0.327 Kcal/m²h °C — 0.067 Btu/h ft² °F.

Step 2 — Air change load

It is assumed that plasma cold rooms are constructed to be properly airtight, and are subject to no air leakage when the doors are shut. However, there is some air change due to storing and removing of plasma.

The infiltration depends on the opening incidence of doors and the duration which doors remain open. The design air change per hour is $\frac{1}{4}$ of volume of the rooms for the average opening frequency; considering that direct flow of low temperature air to outside is prevented by closing the entrance door when the door of freeze chamber is open.

Step 3 — Product load

Although the specific heat of blood was taken to be 0.90 by Stewart; more accurately, Milton Mendlowitz has found the specific heat of whole blood to be 0.87 cal/°C g (*Science, January 23, 1948*).

The experiments are done by the calorimeter method with a view toward determining the effect of viscosity on vascular resistance in the living human subject, it was necessary to be sure that the specific heat of blood did not vary with erythrocyte concentrations. The specific heat of plasma was differentiated, using the same calorimeter with the same hydrothermic equivalent to the specific heat of cells. The specific heat of normal blood plasma was found to be 0.94 cal/°Cg, and for erythrocytes was 0.77 cal/°Cg.

The above specific heat may have minor variations which are attributed to hæmoglobin content of the cell, the percentage of solids such as proteins, or greater concentration of solids, especially iron in the plasma. However, these small discrepancies are not really important for refrigeration product load computation. The referred values are the specific heat at above freezing point, at about 35°C (95°F). There are no references available for specific heat of blood and blood derivatives at the freezing, solid-state. In consequence, the same values are used for freezing calculation.

Considering the specific gravity of whole blood, plasma and erythrocyte, for men, to be 1.0595, 1.0269 and 1.0964 respectively; also noticing other relevant physiochemical data (*Geigy Scientific Tables*) one could take the freezing-point of plasma equal to freezing point of water.

The latent heat of fusion of plasma can be calculated, assuming that a direct relationship exists between the percentage of water content of plasma and the latent heat of fusion of water. Water in blood (*Davis et al, Science 118-276, 1953*);

Whole blood 850 g water/litre (95% range = 830 – 865);

Plasma or serum 945 g water/litre (95% range = 930 – 955).

Since there has been no experimental value yet determined, the following result obtained is an accepted value of latent heat of fusion for complete solidification of plasma for refrigeration practical purposes.

$0.945 \times 80 = 75.60$ Cal/g (316.52 J/g, 136.08 Btu/16).

Step 4 — Miscellaneous load

The amount of heat dissipated by people in the plasma cold storage can be neglected, because the intensity of physical activity is not considerable and the time of human occupancy in the storage rooms is short. Therefore, beside the heat equivalent load of electrical watts due to evaporator fan motors, lights etc., there is no other major load in this step. In conversion of electrical power to heat, the efficiencies and frequency of electrical operation need not be determined.

Step 5 — Total load

The summation of loads calculated separately, would indicate the total hourly load. There is no specific rule for safety factor; it depends upon the design engineer's judgement. In any case, when an accurate calculation is accomplished, the safety factor should not exceed ten per cent (this should take care of heat from plastic bags and other unpredictable loads).

Step 6 — Refrigeration capacity

Generally, the required hourly capacity of the refrigeration system must be decided in connection with 24 hours cooling load estimation. Knowing the essential service of the plasma cold storage and the probable turnover, the design engineer is permitted to use any capacity factor; maximum 18 and minimum 12 hours of refrigerating operation for 24 hours cooling.

Equipment

An engineer who has acquired knowledge about the application of the job can easily choose the major components of the refrigeration system.

The performance and ratings of equipment are accurately tabulated and clearly defined for any stated conditions of temperature and pressure by most reputable manufacturers. The selector is not involved in tedious calculation; only care in selection of the equipment is very important.

The availability of so much information in catalogues and books makes life very easy for refrigeration engineers nowadays.

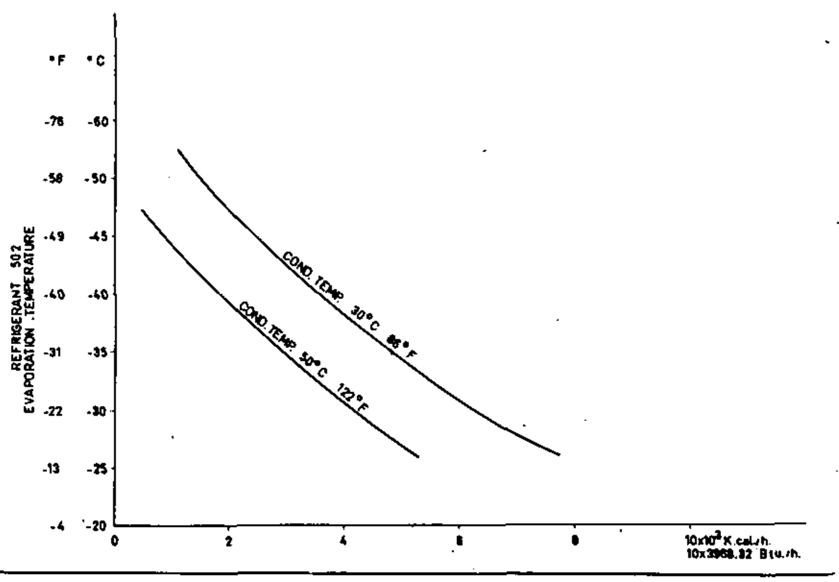
Refrigerant 502 (Azetrope of Dichlorodiflurомethan and Chloropernta-fluoroethane) is the recommended fluid, considering the thermolynamic and economic qualifications of this refrigerant for plasma cold storage.

It is merely interesting to point out that the capacity of a typical compressor in the Persian Gulf area, is almost half as much as its capacity in UK, at – 40°C (– 40°F) evaporating temperature (see *Figure 2*).

Automatic controls

The principles of basic refrigeration controls, such as low pressure cut-off, high pressure cut-off, oil failure control, defrost control, evaporator pressure regulator etc. — which are classified as actuating — and also safety and limit controls are fully described in many text books. There are some additional requirements in primary

Figure 2



controls specified by the health institutions for plasma cold storages, which will be explained in this part.

In this case, the term 'primary controls' refers to a device which is sensitive to temperature. A platinum resistance thermometer bulb provides the most accurate method of temperature measurement. The element of resistance is 100 ohms, and it is inserted into a protecting well which should be properly welded into the wall of the freeze chamber and the cold room. The three-wire system should be connected to a recording and controlling unit. The temperature recorder-controller system will automatically control and record the temperature on a circular chart of 30.5 cm (12 inches) at a speed which will allow a seven-day rotation. The pen records the change of temperature and any difference between the pen and the set point index initiates control action to bring the measured temperature back to the control point.

When the temperature is above $-40°C$ ($-40°F$) the contact will close, an alarm light will be lit, and an alarm will be activated. An acknowledgement push button should be used to silence the alarm, while the light will remain 'on' until the desirable temperature condition is maintained again.

The temperature can also be checked with a separate indicator which is connected to the same sensing element. As the temperature is lowered to the right level multiple compressors, condensers and evaporators should be stopped automatically.

There is a manual switch with four positions:

Position one only allows the refrigeration system to be 'on' or 'off';

Position two allows both compressors to operate together (one compressor is a stand-by) as needed initially for faster freezing;

Position three starts compressor No. 1;

Position four starts compressor No. 2.

Normally one system would be sufficient and should run intermittently. In the case of a system failure, the other system has to come into operation automatically. A control panel board with a suggested dimension of about 200 cm high, 610 cm wide and 46 cm deep (6 ft 7 in × 2 ft × 1 ft 6 in) should include these controls. (See *Figure 3*). A cold room evaporator fan circulates air continuously, while the freeze chamber multi-evaporator fan motors are turned off when the compressor is stopped.

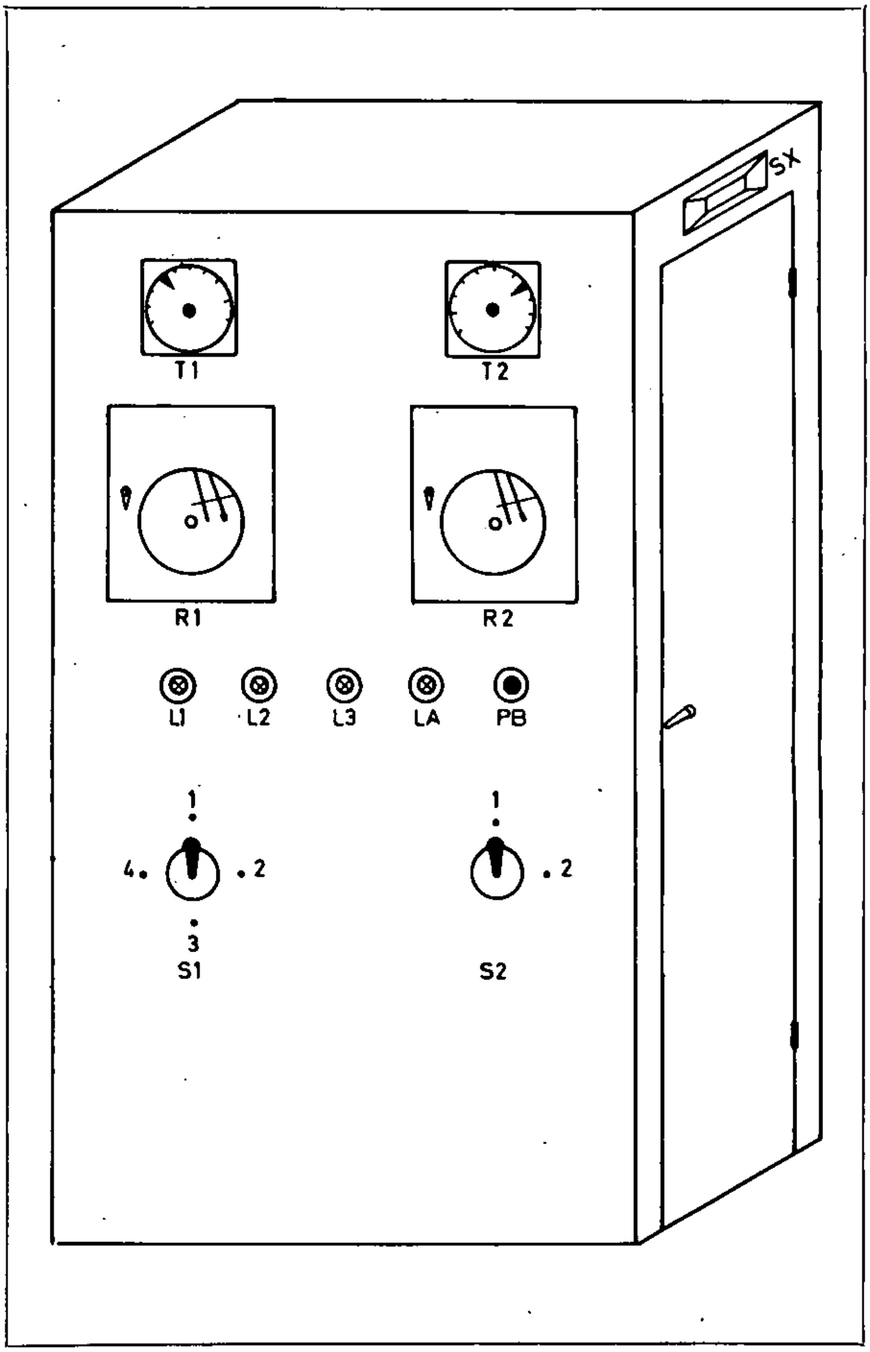


Figure 3

T_1 = Freeze chamber temperature indicator measurement $-70°C$ to $+30°C$ ($-94°F$ to $86°F$)

T_2 = Cold room temperature indicator measurement 0°D to $+30°C$ (32°F to 86°F).

R_1 = Freeze chamber temperature recorder controller

R_2 = Cold room temperature recorder controller

L_1 = Freeze chamber refrigeration system light

L_2 = Freeze chamber stand-by refrigeration light

L_3 = Cold room refrigeration system light

LA — Freeze chamber alarming light

PB — Acknowledgement push button

SX — Siren

S1 — Freeze chamber main operating control switch

S2 — Cold room main operating control switch

Product News

New Mental Illness Unit, Sheffield

A contract, worth about £1.8 million, for a new mental illness unit at Northern General Hospital, Sheffield, has been awarded to J. Dixon (Doncaster) Ltd. by the Trent Regional Health Authority. Building will start in the new year and should be completed in 1979 and be in use later that year.

The unit, located near to the Herries Road entrance behind the existing accident department, will be the first of its kind in the city.

It has been planned in accordance with the concept that the main mental illness services for a District should be part of the services of a district general hospital. The concept is described in the Government white paper 'Better Services for the Mentally Ill'.

The unit will provide initial assessment, treatment and rehabilitation of mainly short-stay patients on a progressive basis. There will be five thirty-bed wards for adults and a thirty-bed unit for adolescent children. In addition, a two hundred place day hospital will provide modern facilities for short term treatment and rehabilitation both for patients in the unit and from the community.

It is hoped that the day hospital will permit earlier discharge of those patients who have recovered sufficiently to leave the ward, but who still need some treatment.

Also included as an integral part of the building is a university sub-professorial unit for the University of Sheffield which will provide facilities for medical teaching and research.

When the unit is open it will provide most of the mental illness service for the northern part of the city. Middlewood Hospital will then provide a service mostly to the rest of the city.

The new mental illness unit is the second of the two most urgently needed parts of the original first phase of development at Northern General Hospital. With the accident department about two-fifths of the original first phase scheme is now proceeding.

The progress of the remainder will depend on the resources available for Health Service building and the relative priorities attached to them by the Regional Health Authority and the Sheffield Area Health Authority (Teaching) compared with other needs.

New BSI Standard

Safety of Industrial Cleaning Machines

The base document for a series of specifications relating to safety of industrial electrical cleaning equipment and two sections covering particular requirements for specific items are now published by the British Standards Institution. BS 5415 *Safety of electrical motor-operated industrial cleaning appliances* is in two parts. Part 1 *General requirements* is published; it is the base document for Part 2 publications and reads in conjunction with them. Thirty clauses cover general topics and a wide range of requirements common to many types of appliance, e.g. shock protection, starting, input, heating, overload, insulation, interference suppression, resistance to moisture, to heat and to rusting, strength, construction, internal wiring, supply connection, terminals for external conductors, earthing, creepage distances, clearances and distances through insulation.

Two sections of Part 2 *Particular requirements* are also published. Section 2.1 *Floor polishing, scrubbing and/or carpet cleaning machines* covers machines with or without attachments and those with wet or dry suction. Section 2.2 *Vacuum cleaners wet and/or dry* covers machines with or without attachments.

These publications may be obtained from: *BSI Sales Department, 101 Pentonville Road, London N1 9ND. Prices: BS 5415 Part 1 £6.60, Part 2 (2.1) £1.60, (2.2) £2.70.*

Stannah Economy Stairlift

A new economy stairlift, designed to ease the problems of the elderly, disabled and infirm, has been introduced by Stannah Lifts Ltd.

Designed for 'straight line' applications where space is restricted, the rail of the stairlift occupies only 150 mm (6 ins) of stair width.

The chair occupies only 400 mm (1 ft 4 ins) when parked. There is no separate power unit. Control push buttons are fitted to the chair, and remote control push buttons are fitted at the top and bottom of the rail.

Further information: *Stannah Lifts Ltd., 49/51 Tiverton Street, London SE1 6PA (01-407 4224).*

Radio Tracing Probe for Pipes Down to 2 ins

A new, miniature and very flexible, radio transmitting probe for use in tracing drains, sewers or pipes down to as small as 50 mm (2 ins) diameter has been introduced by Electrolocation Limited, Bristol (a Rotork company).

Designated the 'Flexiprobe', it can be purchased separately or as part of the company's new sub-surface electronic survey equipment, which includes instruments designed to locate, track and estimate the depth of most underground services.

To achieve the necessary compactness and flexibility of operation the probe comprises only a transmitting aerial at the lead end of a 30 m length of semi-rigid nylon hose; battery and control circuits are at the trailing — operating — end, thereby reducing the bulk that needs to enter the pipe or channel. The lead end is fitted with a wheeled nose-piece to assist passage. From one set of dry-cell batteries the probe has an average operating life of two to three days according to intensity of use.

Further information: *Electrolocation Limited, 129 South Liberty Lane, Bristol BS3 2SZ. Tel. 0272 634383.*

Electrolocation's new tracing probe supplied with 30 m hose.

Jacob, White and Rosebery Metal merge

Jacob, White (Hospital Equipment) Ltd. of Dartford, Kent, recently incorporated the Rosebery Metal Works Co. Ltd. of Highbury, London N5, into their own organisation. The purchase of this company which has now been established for over 75 years adds many items of Hospital Equipment to the already extensive range produced and marketed by Jacob, White.

Items of particular interest recently added either to Rosebery Metal Works, or Jacob, White's products include a Gas Cylinder Elevating Surgeon's/Anaesthetist's Stool, a complete range of Bedpan Washers and a range of Ultrasonic Cleaners.

All enquiries relating to the Rosebery Metal Works Co. Ltd. should now be addressed to the Riverside Industrial Estate, Riverside Way, Dartford, Kent. Tel. Dartford 23267.

Cass Electronics Health Care Communication

Cass Electronics Limited, well known for their Teletracer hospital and nurse call communication systems, have developed an entirely new range of very functional, modular signalling and communication units for wall mounting.

The Cass international design team have created this new concept featuring just four basic sizes of module both of which will readily snap into conduit boxes with 20 mm and 25 mm 'knockout'. Surface frames are also available.

Printed circuit boards carrying the selected components form part of the fascia plate assembly which is simply snapped into position, with no exposed screws or bolt heads.

The incorporation of all nurse call, paging and bedside radio communications within a modular format will be seen to be both economical and practical.

Further information: *Cass Electronics Limited, Crabtree Road, Thorpe, Surrey.*

St. George and the Portastor

Modern day fire-producing monsters will pose few problems for the new St. George's Hospital, London! In fact they will be kept well under control by a new Portastor flammable materials unit.

St. George's is now moving from Hyde Park Corner to Tooting in South West London. Phase 1 of the multi-million pound first stage of construction — the nursing and medical schools — was handed over at the end of 1976. Included along with other advanced facilities in the student teaching labs and main pre-clinical departments is the Portastor flammable materials unit recently developed by Portasilo Limited of York.

The 100 cu ft unit will be used as a temporary solvent store to house highly flammable chemicals needed by the Medical School and Research Laboratories, and which are too dangerous to be kept in the actual hospital buildings.

Weighing three tons, the unit is built like a tank. The roof and walls are constructed from galvanised pressed steel and lined with fire resistant board which gives an internal half-hour resistance to flames. In addition, all electrical lighting and wiring installations are completely flameproof.

To cope with accidental spillage, the floor is lined with galvanised steel with a vertical skirting which forms a 'tray' to retain liquid spillage. The floor is overlaced with a removable open mesh of galvanised steel to ensure all spillage of corrosive materials drops through into the 'tray'.

The Portastor will be used in its present role until permanent stores are built in stage 1 of the hospital contract. An added bonus is that the one-piece building can be easily resited — a factor to consider with the changing layout of a new hospital complex.

Kimberley-Bingham Range information

Helpful information for Hospital Buyers is now available in the form of a new catalogue about a range of aids and equipment supplied by the Delta Group member, Kimberley-Bingham and Company Limited, of Birmingham. Established in 1951, Kimberley-Bingham have earned a reputation as suppliers of high quality rehabilitation equipment and aids of all kinds.

The new catalogue, containing photographs and technical details, describes equipment such as hoists and wheelchairs, bathroom aids — safety rails, seats and mats, and permanent fixtures — grab rails and support rails. Many other items are included to assist patients to achieve complete independence during their daily activities.

Full details and a set of data sheets are freely available from: *Kimberley-Bingham and Company Limited, 111 High Street, Bordesley, Birmingham B12 0JS. Tel. 021-773 6166.*

Woolliscroft Ceramic Tiles

Unglazed ceramic floor tiles by George Woolliscroft & Son Ltd., of Hanley, Stoke-on-Trent, have been chosen for three important new hospital contracts. In each case, Woolliscroft tiles have been chosen to provide a versatile and hard-wearing floor for specific floor areas.

This follows closely on the recommendations of the National Building Agency in its guide to wall and floor finishes, a cost-in-use approach, which suggests that for many floor areas, such as ancilliary hospital rooms, ceramic tiles are the most economical choice of floor.

Woolliscroft buff tiles, in a plain and a Supergrip slip resistant surface, have been chosen for use in a number of areas at the new Sandwell District General Hospital, West Bromwich. These include floor areas in physiotherapy rooms, shower areas, post mortem rooms, pharmacy, accident area and the kitchens.

Almost 30,000 Woolliscroft tiles, in a plain buff colour size 200 mm X 100 mm X 9.5 mm were chosen for use at the John Radcliffe Hospital, near Oxford, where they are being laid as flooring to the main building kitchen and to the blood bank area.

The third current contract covers the window cills, shower and bath area of the new Guildford Hospital where Woolliscroft plain black tiles are being fixed.

Woolliscroft ceramic tiles are resistant to acids and abrasion and they have a fine surface finish which makes them easy to clean and thus maintain a high standard of hygiene. The tiles are produced from natural clays which have been slipped and purified before being Kiln baked to a very high temperature.

Further information: *George Woolliscroft & Son Ltd., Melville Street, Hanley, Stoke-on-Trent ST1 3ND. Tel. 0782 25121.*

Classified Advertisements

APPOINTMENTS AND SITUATIONS VACANT

CLASSIFIED ADVERTISEMENTS — *continued from previous page*

APPOINTMENTS AND SITUATIONS VACANT

Greenwich Health District

Based at Greenwich District Hospital, Vanbrugh Hill, London SE10 9HE

Assistant Engineer

Applicants must be well experienced in the operation and maintenance of large air conditioning units, and their associated plant and controls, refrigeration machines etc., and will be responsible to the Hospital Engineer for carrying out this function at Greenwich District Hospital, although he or she will be expected to assist over the whole range of an Assistant Engineer's duties if required.

This is a new Hospital, fully air conditioned. The work is interesting but very demanding, requiring the services of a skilled and energetic Engineer. It is stressed that this is not a training post.

Applicants must have served an engineering apprenticeship and possess an O.N.C. in mechanical or electrical engineering, or recognised equivalent. Hospital experience is not important.

Salary scale £3,708 to £4,152, inclusive of London Weighting and earning supplement (starting salary may be above minimum for a suitably qualified and experienced person).

Temporary single accommodation may be made available.

Mr. N. Kenney, Sector Engineer, or Mr. G. Hughes, Hospital Engineer, would be pleased to discuss technical details with interested persons, telephone 01-858 8141.

Further details and application forms from the Personnel Officer, Greenwich District Hospital, Vanbrugh Hill, London SE10 9HE.

Closing date for receipt of applications: 1st April, 1977.

Hounslow Health District
West Middlesex Hospital
Isleworth, Middlesex

DISTRICT ENGINEER

Applications are invited from suitably qualified and experienced officers working in the N.H.S. (including post graduate Teaching Hospitals) for the post of District Engineer to the Hounslow Health District. This District comprises six hospitals and several clinics and Health Centres and offers an excellent opportunity to gain valuable experience in the Health Service engineering field. Salary on scale £5,763 p.a. rising to £6,945 p.a., plus £354 p.a. London Weighting and £291 p.a. Supplement.

Application form and job description from, and returnable to, Mr. P. J. Harris, Assistant Senior Personnel Officer.

For further details please contact Mr. D. Alexander, Acting District Works Officer. Closing date: 18th March, 1977.

Index to Advertisers

To place an advertisement in the next issue, appearing **APRIL 1**
contact Sue Cartwright at

EARLSPORT PUBLICATIONS
33 Ludgate Hill, London EC4
or phone: **01-248 0148**
by **Thursday, March 24** latest

EQUIPMENT

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HOSPITAL ENGINEERING

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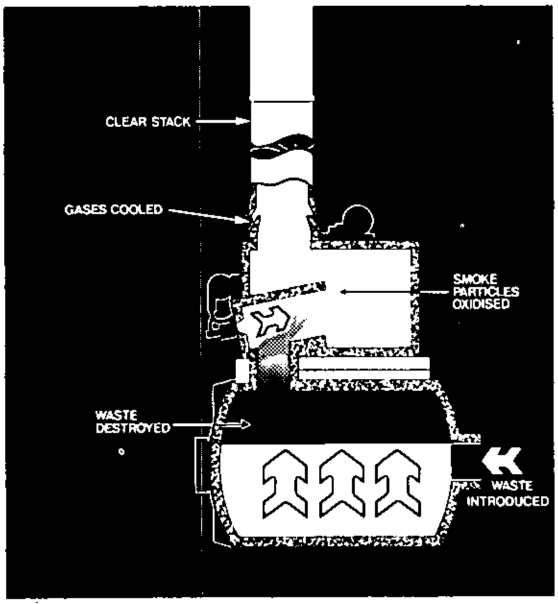

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