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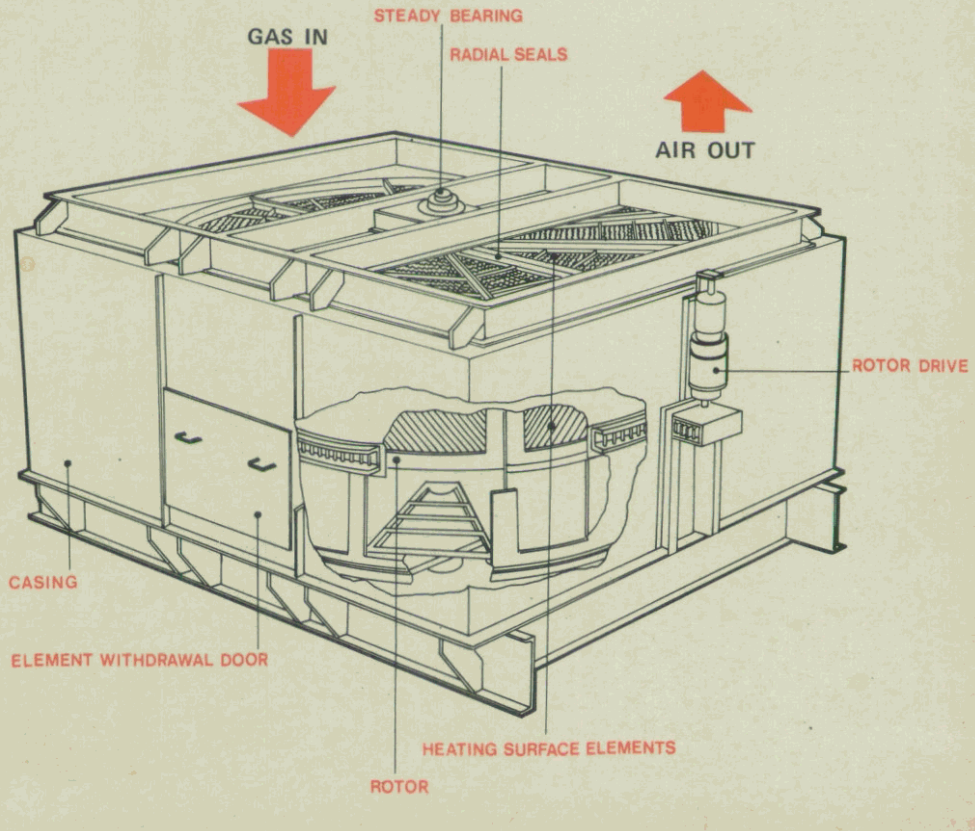
Hospital Engineering

OCTOBER 1976



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Hospital Engineering
Incorporating 'The Hospital Engineer'

Vol. 30
October 1976

The Journal of The Institute of Hospital Engineering

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Editorial

With this issue, *Hospital Engineering* enters a new era. The publication of the Journal has for the last seven years been in the capable hands of Peter Peregrinus Limited. Now the Council has decided to ask a new team to take over, and from this issue the publisher is Earlsport Limited, acting in conjunction with the printing firm, JB Offset Limited. The Editor will be Christopher Tanous, a technical journalist who has previously been a member of the editorial staffs of journals in the transport and financial fields.

The Editor writes: Our aim is to continue the successful development of Hospital Engineering as a means of communication between the Institute of Hospital Engineering, its individual members and other readers, and the many bodies with whom they have contact.

It is hoped to give more news of the formal — and informal — proceedings of the Institute, and more coverage of new techniques and equipment, without affecting what must remain the main purpose of the Journal — to present technical articles and discussion as well as possible.

Of course, communication is a two-way process. We hope that readers will continue to support their Journal by making fullest use of it. To this end we will continue to welcome articles, letters, and news items for publication — either direct to our London address, or via the Secretary of the Institute.

Christopher Tanous — Editor

Institute News

The Institute of Hospital Engineering

The Design of Security Units

One-day Symposium
to be held at
The Institution of Mechanical Engineers
2 Birdcage Walk, Westminster, London
on
Wednesday, October 20, 1976

As a result of recommendations made by the Butler Committee on Abnormal Offenders, the National Health Service is required to provide units which can offer security. The Department of Health and Social Security has emphasised the urgency for these units in the Consultative Document "Priorities for Health and Personal Social Services in England" by making special finance available for them.

It is the purpose of this Symposium to provide an opportunity for the various disciplines to debate the way in which these policies can be accommodated.

Programme

CHAIRMAN: Dr. M. J. MacCullock, MB ChB DPM MD MRCPsych
Principal Medical Officer, Department of Health and Social Security.

10.00 Assembly and Coffee.

10.30 **The Type of Patient and Behaviour Patterns**
Speaker: Dr. R. BLUGLASS, MD FRCPsych DPM
Consultant Forensic Psychiatrist, Midland Centre for Forensic Psychiatry.

11.00 **Nursing Policies**
Speaker: C. LAKE Esq, RMN, RNMS, SRN
Nursing Officer, Department of Health and Social Security.

11.30 **Architectural Considerations**
Speaker: JOHN INGHAM Esq, FRIBA
Regional Architect, South West Thames Regional Health Authority.

12.15 Lunch

14.00 **Engineering Considerations**
Speaker: P. H. Parker Esq, CEng, FIEE MIHVE FIHospE
Regional Engineer, Trent Regional Health Authority.

14.45 **Open Forum — Questions and Discussion**

16.30 **Closure**

Tickets, price £8 (eight pounds) (includes LUNCH) obtainable ONLY from: Secretary, The Institute of Hospital Engineering, 20 Landport Terrace, Southsea PO1 2RG.

West of Scotland Branch

Date	Event	Venue
Thursday 28th October 1976	**Visit to Hunstanton Nuclear Power Stations,** Ayrshire.	
Thursday 25th November 1976	**"Operation of NICEIC"** — Mr. G. D. Sweeney, Inspecting Engineer, National Inspection Council for Electrical Installation Contracting.	CGHB, Sauchiehall Street, Glasgow.

South Western Branch

With the rising costs of postage, the Committee have decided that in an effort to reduce costs, Circulars will not be sent before each meeting or visit.

Date	Event	Venue and Time
Wednesday 20th October 1976	**Lecture on Solar Energy in Health Service Buildings** given by Mr. B. James, Assistant Engineer to the South Western Regional Health Authority.	7.30 pm The Medical School Lecture Theatre, Southmead Hospital, Bristol.
Wednesday 10th November 1976	**Visit to Aust Cable Tunnel Site** at the Severn Bridge. N.B. The numbers for this visit are severely restricted.	7 pm Access is via M5 Aust Junction (Severn Bridge). The Private CEGB Road is well signposted as you approach the Aust Services.
Thursday 9th December 1976	**Lecture on Boiler and Pressure Vessel Failures** given by Mr. J. E. Gander, Engineer Surveyor with the Municipal and Mutual Insurance Group.	7.30 pm The Conference Room, Bristol Royal Hospital, Radio-therapy Centre, Horfield Road, Bristol BS2 8ED.

Mid Scotland Branch

The following posts have been filled in the Mid-Scotland Branch:

Tayside Area Health Board

Mr. A. G. Keddie	Area Maintenance Engineer
Mr. G. Walker	Area Engineer
Mr. J. Y. Nicol	District Engineer Dundee
Mr. R. G. Paul	District Engineer Perth
Mr. J. McNeil	District Engineer Angus

Grampian Area Health Board

Mr. F. C. Moncrieff	Area Maintenance Manager
Mr. Yule	Area Engineer
Mr. W. Runcie	District Engineer South District
Mr. A. Baxter	District Engineer North District
Mr. W. Sutherland	District Engineer West District

Highland Area Health Board

Mr. B. G. Short	Area Maintenance Manager
Mr. G. Doherty	District Engineer (Southern)
Mr. H. S. Staines	District Engineer (North)

Fife Area Health Board

Mr. G. T. Millican	Area Maintenance Manager
Mr. W. McArthur	District Engineer (East)
Mr. T. Ireland	District Engineer (West)

North West Branch

At the 1976 Annual General Meeting the following Branch Officers were elected for the current year:

Chairman:	W. J. SMITH
Vice-Chairman:	R. RICHARDS
Hon. Secretary:	D. CUNLIFFE, 3 Lowerfold Close, Rochdale, Lancs. OL12 7HY

Institute Library

It will be of interest to Members to know of the following recent additions to the Library. These can be obtained on loan in the normal way from the Institute Honorary Librarian, R. G. Smith, "Kewstoke", Primrose Lane, Oversley Green, Alcester, Warwickshire B49 6LG.

An Introduction to Heat Pumps
John A. Sumner

Handbook of Environmental Control — Vol. 5 (Hospital and Health Care Facilities)
Conrad P. Straub

I.E.E. Medical Electronics — Monographs — 13-17
Edited by D. W. Hill and B. W. Watson

Commissioning Hospital Buildings
King Edward's Hospital Fund

Fire Safety Training in Health Care Institutions
The American Hospital Association

Materials of Construction for Steam Power Plant
L. M. Wyatt

Public Health Engineering for Hospitals:

Some Current Developments

The report of the proceedings of the symposium held in September 1975 at Brunel University have been published and are available at a price of £10 per copy from the Institution of Public Health Engineers, 32 Eccleston Square, London SW1V 1PB.

Retirement

Alan Marshall and Partners, Consulting Civil and Structural Engineers, announce that Dr. K. J. Brown has retired as a Partner, but his services have been retained as a Consultant. The name and address of the Practice will remain unchanged.

Just over fifty years ago the idea of a rotary heat wheel or regenerative air preheater was born. Frederick Ljungstrom, *the famous Swedish engineer who was honoured by the Institution of Mechanical Engineers in 1949 for his contribution to the development of Mechanical Engineering, invented and patented the rotary regenerative air preheater in 1922. W. A. Drummond, Manager, Heat Exchangers, for James Howden and Company Limited of Glasgow explains how fuel savings can be made.*

Development of the Rotary Air Preheater

W. A. DRUMMOND

The basic idea of using a slowly rotating drum containing a tightly packed heating surface matrix to transfer heat from boiler flue gases to cold combustion air is still the basis for present day designs although the number of applications is now much greater, covering industrial boilers and furnaces in a wide range of industries.

Waste heat recovery with this design of preheater has of course been utilised for very many years. In Great Britain alone the Ljungstrom manufacturer James Howden & Co. Ltd., of Glasgow has manufactured over 3000 units.

Design Features of the Rotary Air Preheater

The essential features of the rotary air preheater are the rotor, the heating surface elements, and the housing, the construction being arranged to direct flue gases through one side of the rotor and air for combustion through the other side. See *Figure 1*. As the rotor revolves slowly, the elements are heated in the gas side of the preheater and then give up their heat to the air as they pass through the air side. There is thus a continuous cycle of heat transfer from gas to air. The heating surface elements are normally mild steel sheets notched and undulated to give a high degree of turbulence and heat transfer.

The preheater can be arranged for either vertical or horizontal air and gas flow to suit boilerhouse layout. See *Figure 2*. The vertical shaft design has the weight of the rotor supported at one end by a spherically seated roller thrust bearing located in the preheater support structure. The rotor shaft at the other end revolves in a steady bearing which eliminates sideways movement.

The horizontal shaft design has two stub shafts bolted to the rotor and carried on self-aligning roller bearings which are supported by beam structures integral with the air preheater housing. Apart from the supporting arrangement the general construction of rotor and housing are similar in vertical and horizontal designs, the rotor drive being supplied in both cases by an electric motor and reduction gear unit which drives a rack on the rotor shell.

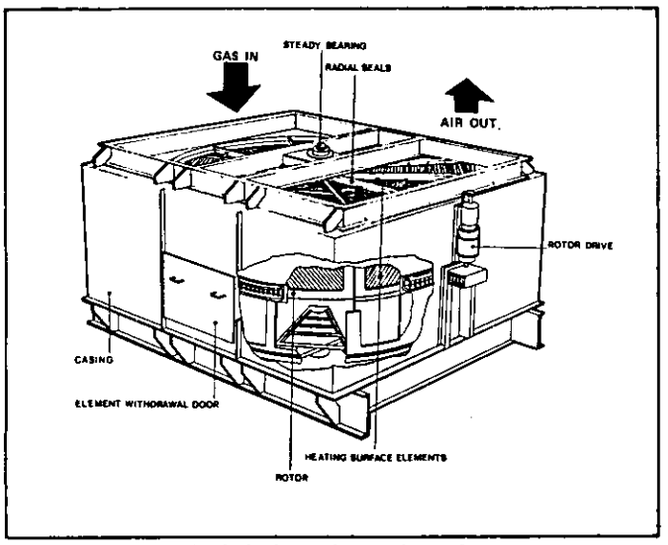
The small running clearances between the rotor and the housing result in some leakage of air to the gas side. Sealing strips are fitted to the rotor and are adjusted so that they are just clear of the stationary sealing plates when the air preheater is at working temperature. Radial seals are fitted at both ends of the rotor to control direct leakage of air to the gas side. Circumferential seals are also fitted round the rotor edges and at the hub at both hot and cold ends. These run against annular flanges fixed to the housing end plates.

The forced draught and induced draught fan volumes are increased by air preheater leakage, thereby resulting in a slight increase in the power required to drive the fans. Although the effect of leakage in the air preheater is almost negligible so far as overall boiler efficiency is concerned, it has to be taken into account in designing the fans.

The rotor seals are subject to wear and have therefore to be replaced from time to time.

Heating Surface

In certain installations, particularly on oil-fired boilers, the low gas leaving



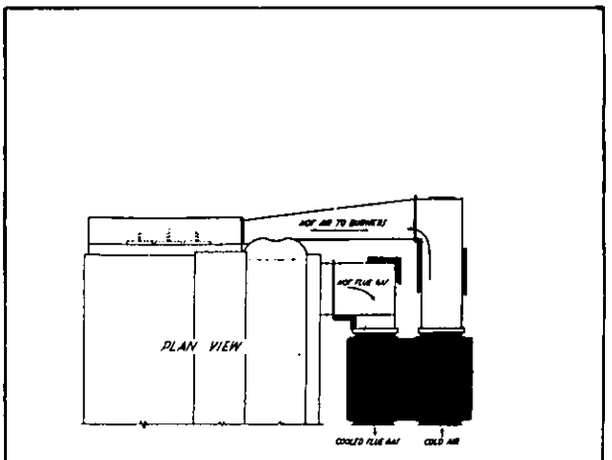


FIGURE 1: Vertical shaft package air preheater.

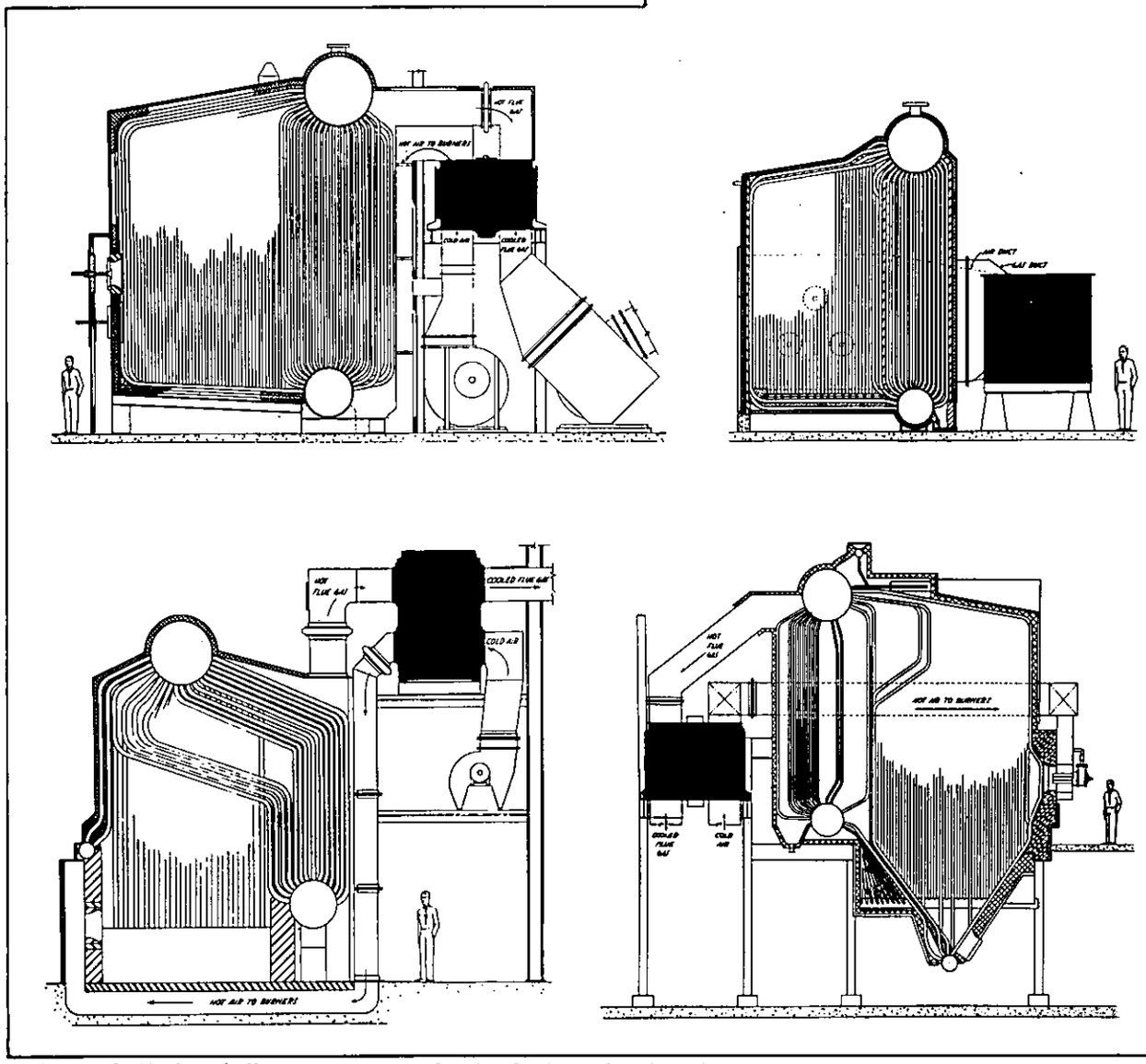


FIGURE 2: Various boiler arrangements showing horizontal and vertical shaft preheaters.

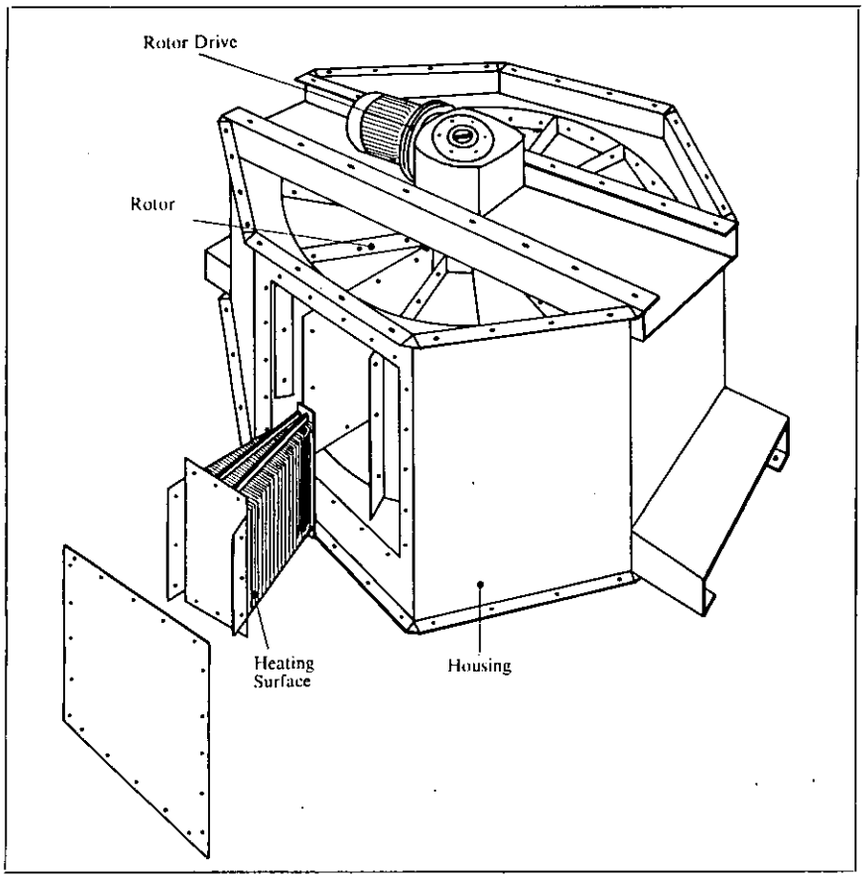


FIGURE 3: New design "Mini" package preheater.

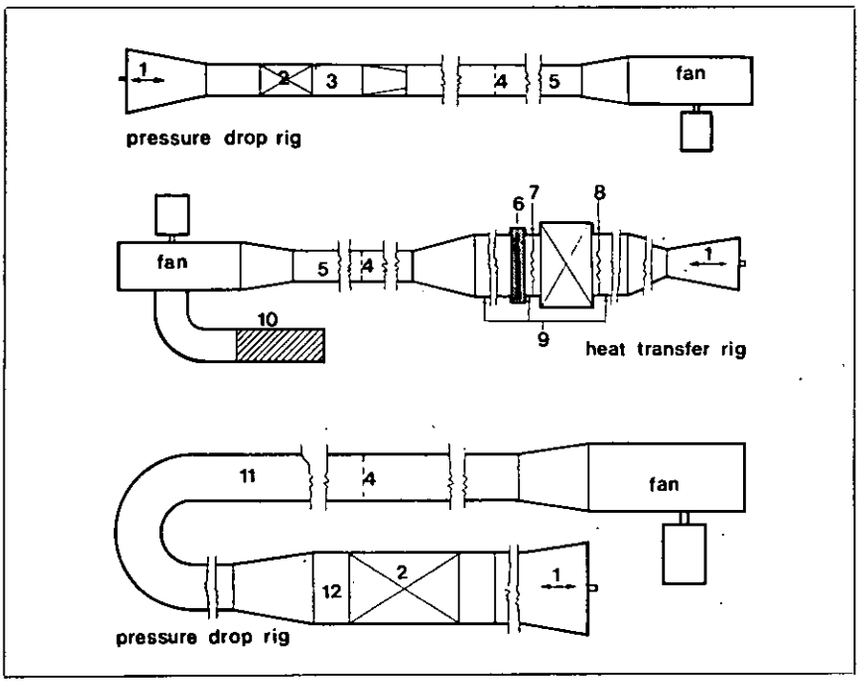


FIGURE 4: Air preheater element test rigs.. 1, damper; 2, element test pack; 3, 6" sq duct; 4, orifice; 5, 6" dia duct; 6, gauze heater; 7, inlet resistance thermometer; 8, outlet resistance thermometer; 9, 12" wide × 6" deep ducts; 10, suction (thermal damper); 11, 13" dia duct; 12, 24" wide × 6" deep duct.

temperature necessary for high boiler efficiencies can result in corrosion occurring at the cold end of the air preheater. Low temperature corrosion can, of course, be largely eliminated by raising the metal temperature above the acid dewpoint and accepting the resultant reduction in heat recovery. It is more economical however, to maintain reasonably low gas outlet temperatures as the saving in fuel costs will greatly outweigh the cost of replacing the cold end elements, providing a minimum element life of about nine months is obtained.

It is generally acceptable to use mild steel for the hot end heating surface and Corten, which is a copper bearing corrosion resistant mild steel, for the cold end. For corrosive conditions Corten has been proved to be the most economic material, from the point of view of first cost and frequency of replacement. For very corrosive conditions a vitreous enamelled mild steel is sometimes used.

The heating surface is kept clean by steam or compressed air sootblowers which are fitted in the gas inlet and outlet duct connections.

New Developments

Package Design

With the rapid increase in fuel prices over the past two-three years many industries have become acutely aware of the need for improved energy conservation. Economic conditions have however demanded the closest scrutiny and control of all capital expenditure even in cases where a rapid return in capital is proven — as in the case of many heat recovery schemes.

This situation has led to the development of a new low cost rotary regenerator designed specifically for the low end of the boiler size range. This design is shown in *Figure 3.* and can be used with small industrial boilers down to 10,000 lbs/hr evaporation.

In developing this so-called "mini package" design, the opportunity has been taken to introduce improvements in the sealing system which lead to a reduction in leakage of air to the gas side.

Heating Surface

At an early stage in the development of the Ljungstrom preheater it was realised that the heat recovery poten-

tial of these units was intimately associated with detail geometry of the heat transfer surface. As a result considerable development effort was invested in determining by experimental techniques, the optimum geometry. Initially, the heat transfer characteristics of elements were determined from laboratory tests using fairly crude equipment. However the testing techniques have been the subject of considerable development effort by Howden who now possess and operate a heat transfer test rig which is thought to be unique (see *Figure 4*).

Two independent test methods are available with this rig, the traditional single blow transient method, and the cyclic or steady state method.

In the transient method atmospheric air is blown through the test pack of elements until the pack and air are at uniform temperature. The temperature of the air at inlet to the pack is then instantaneously increased by about 10°C by switching on the gauze electric heater. The temperatures at inlet and outlet of the pack are measured by resistance thermometers and recorded, typically, within five seconds of temperature differentials being established. Alternatively recordings can be taken until the outlet temperature approaches the inlet temperature — see *Figure 5*. The test is repeated for various flows over the normal working range of the regenerator. The analysis of the temperature curves obtained, gives the thermal performance of the test elements. This analysis depends on the solution of partial differential equations for which techniques not previously available are used, based on the computer.

In the Cyclic method the inlet air temperature to the test pack is made to vary sinusoidally and the pack is allowed to settle down until the outlet temperature attains a steady sinusoidal pattern. The air temperature decays exponentially as it passes through the pack and the ratio of inlet and outlet amplitudes — see *Figure 6* — is a measure of the heat transfer performance of the elements. There is also a phase shift on the outlet sine wave compared with the inlet and theoretically this shift can also be used as a measure of performance although in practice an acceptable accuracy is difficult to achieve. With this cyclic method use is also made of the computer to solve the complex equations involved in analy-

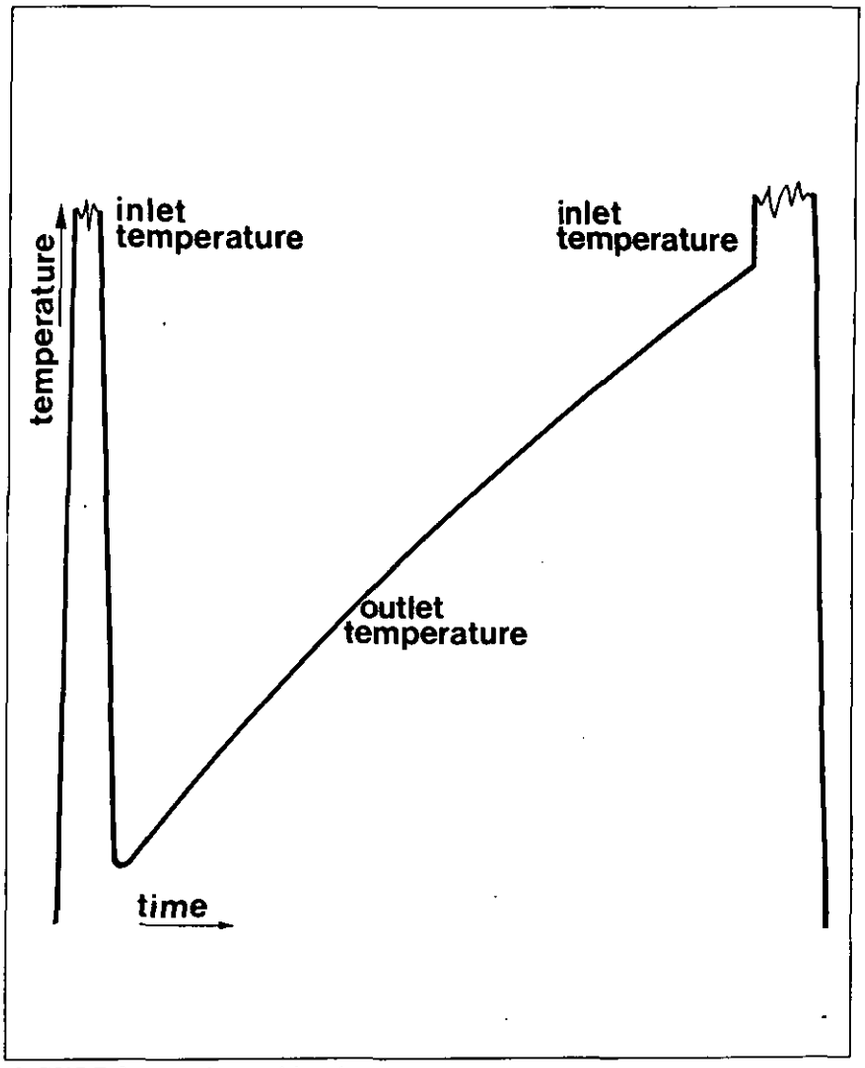


FIGURE 5: Experimental heating curve.

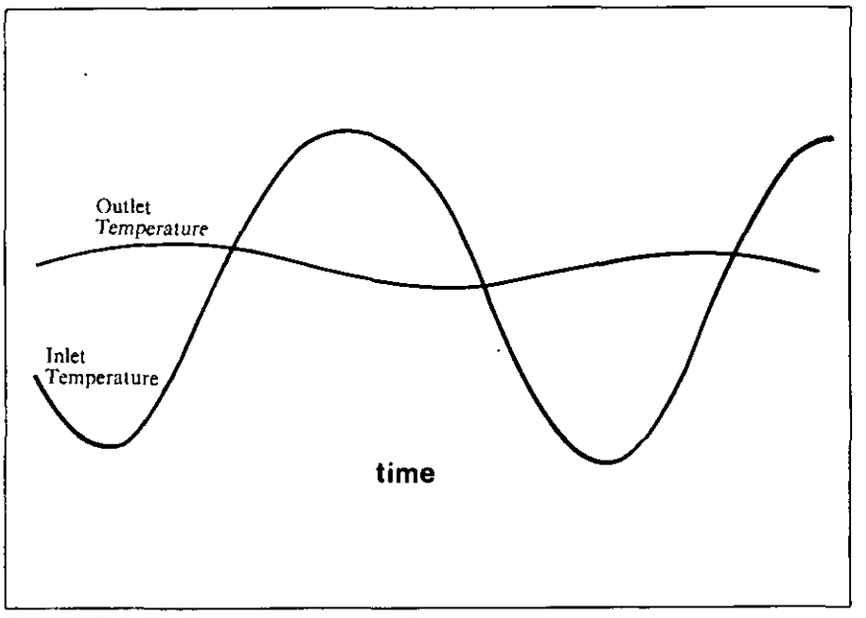


FIGURE 6: Cyclic test temperature traces.

sis of the test results.

In association with these heat transfer tests, of course, pressure drop tests are carried out in separate test rigs — see *Figure 4*. An optimum heating surface shape for a specific application can only be determined by comparing the pressure drop and heat transfer characteristics of all elements tested.

The outcome of this work has been to produce a group of optimum heating surface shapes, each shape being suitable for a particular fuel or application. *Figure 7* shows three such shapes, the corrugated undulated (CU) for applications where heavy fouling is anticipated, the double undulated (DU) for applications where only moderate fouling is anticipated and flat notched crossed (FNC) for clean conditions. The dimensions of each of these shapes has been optimised in a series of laboratory tests as described above.

Other shapes which have been tested include crossed rods, wire mesh, ceramic and vitreous enamelled sheet.

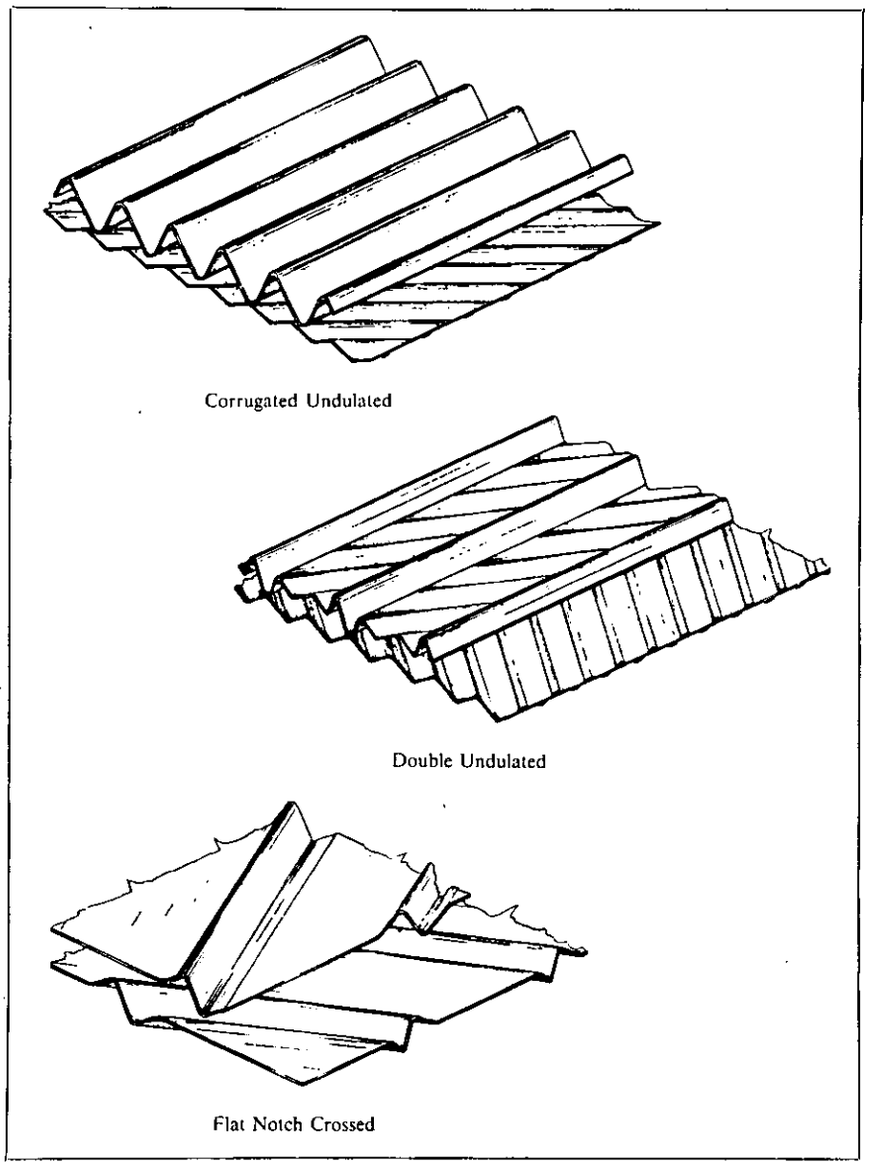


FIGURE 7.

Economic Justification

When designing new boiler units it is not too difficult to decide the extent of waste heat recovery equipment required, in the light of current and anticipated fuel and power costs. The capital and capitalised running cost including cost of maintenance of the plant must be justified by a satisfactory return in terms of fuel cost saving.

However, there are many existing boiler units now operating, which were designed when fuel costs were not as high as they are today. These boilers were designed for flue gas temperatures which, on today's fuel costs, seem excessively high. In such cases it is appropriate to consider the possibility of increasing the size of existing heat recovery equipment or of installing additional equipment at the back end of the boiler to bring the stack temperature down to a more economical level.

This can only be justified if the value of the fuel savings repay the total capital expenditure in a reasonably short time. A maximum "pay back" period of two-three years is frequently considered to be satisfactory.

It has to be borne in mind that the capital cost of the project has to include not only the cost of the preheater, but also the cost of ducting, steelwork, fan modifications if necessary, and the like.

For the installation of a preheater on an existing boiler plant it is commonly found that the preheater cost represents only about one third of the total capital outlay.

It must also be stressed that the annual fuel savings achieved are offset slightly by the increased running cost of the fans and increased maintenance.

In spite of these factors economic studies on many plants have shown that very short "pay back" periods can be achieved, even less than one year in some instances.

Conclusion

Rotary air preheaters are now not only supplied for power stations and industrial boilers, but also for oil refinery distillation units, methanol and ammonia furnaces, copper and steel furnaces and other applications including marine.

The success of the rotary preheater, or heat wheel as it is sometimes called, in these fields has stimulated a tremendous interest in industry generally and to assist customers in assessing the potential fuel savings to be gained from preheaters James Howden offer an Energy/Process Consultancy Service which is fully backed up by their Engineering and Research resources.

Doctor Lidwell, of the Central Public Health Authority, presented this interesting and challenging paper at the Institute's one-day symposium held at the Imperial College of Science and Technology in London on June 23, 1976.

Clean Air, Less Infection.

Dr. O. M. LIDWELL, DPhil

The very nature of a hospital where many people are brought into intimate contact in a close community provides numerous possibilities for the exchange of micro-organisms. Fortunately most of these exchanges are quite harmless and have no perceptible consequences. Among the patients there are, however, those who are more susceptible than normal to disease as a consequence of infection with a "foreign" organism. This may be due to the condition which brought them into the hospital in the first place or to the treatment they receive, including surgery or the administration of drugs.

There are also present at the same time those admitted with some infective condition, by which we mean that they carry micro-organisms more apt than most to produce disease in susceptible individuals. The interchange of micro-organisms between patients, staff and, sometimes, visitors in the peculiar environment of the hospital favours some strains or species as against others, so that the micro-flora of the hospital differ from those of the community outside. "Hospital" strains of e.g. *Staphylococcus aureus* resistant to many antibiotics often constitute a substantial fraction of the flora. For most of the patients acquisition of these is without clinical consequences, but in some the infection produces clinically apparent disease which may be difficult to treat if antibiotics are ineffective. Limitation of the extent of the exchange of micro-organisms between the inhabitants of a hospital is, therefore, an essential part of a disease control programme. The object of this paper is to point out some of the factors and to consider what part control of airborne transport may play.

Changes in organisation and in the procedures carried out, resulting from changes in medical knowledge and practice, will lead to changes in the relative importance of the different routes of infection. Hospital infection studies can, therefore, yield no final answers but must continually attempt an assessment of the current situation in order to indicate the most effective and economical means for reducing disease due to infection to as low a level as possible.

Routes of Infection

The acquisition of an infection must involve in some way or other these stages: —

1. A source of the micro-organism;
2. Dispersal of this from the source;
3. Transfer through the environment;
4. Deposition on a susceptible site;
5. Multiplication.

Whether the infection leads to disease depends on the properties of the organism, the susceptibility of the host and the site of infection. At a sensitive site in a sufficiently susceptible individual almost any organism may multiply and lead to disease as e.g. on an artificial heart valve. There are therefore, few, if any, wholly non-pathogenic organisms, even although a very small proportion of infections may actually cause disease.

Transfer of infection can, in principle, be prevented at any one of the above stages.

The source is usually a person or persons. Control measures can be applied to those infected with unusually virulent strains, or who disperse their flora to an abnormal degree. Such measures include removal from the environment e.g. of staff, including food handlers, who present an unusual risk; segregation i.e. placing of patients in isolation; and treatment of staff or patients to eliminate the infection or restrict dispersal.

Dispersal is closely associated with activity, although surprisingly little movement is needed to disperse the skin scales which are continually being shed from the body surface and which provide the major dispersal mechanism for e.g. *Staph. aureus*. Dispersal from patients in hospital is about half as great during night-time hours as during the day.

Deposition from the air implies exposure of the sensitive area, but infection by inhalation is not very easily controlled. The average person inhales, and retains most of the particles from about 15-20 cubic metres of air per day. Contact with contaminated objects and with hands clearly presents the most obvious opportunity for the transfer of large doses of infective material.

Initiation of infection by the multiplication of the transferred dose involves many factors. Although most experimental studies suggest that large numbers of viable cells are required in healthy tissue the numbers may be greatly reduced in the presence of a foreign body or if the body defences are depressed by drugs or disease. Protection may be given by immunisation or by antimicrobial drugs but there are still many areas of ignorance in relation to the workings of the natural defence mechanisms. Future

work here might revolutionise our ideas on the control of infection.

We are likely however, to be always concerned with the ways in which infection is mechanically transferred within the environment from source to sensitive site. However successful control measures applied to the other stages may be, they are unlikely to be 100% effective and reduction in the extent of transfer by means of a bacteriologically clean environment reduces the challenge to the potential host.

Transfer within the environment is, or may be, a very complex process. The possible routes are very numerous and can be direct or stepwise. *Figure 1* shows some possible routes applied to the relatively simple circumstances of a surgical operation. The different pathways may vary enormously in effectiveness. A septic finger in a perforated glove could deliver an overwhelming dose. Sedimentation from the air onto a scalpel blade is hardly likely to introduce more than a few organisms. Some organisms, such as many gram-negative species, die rapidly if they become dry and so any effective route must be quick. Others, e.g. clostridial spores, survive almost indefinitely. The problem is to apply effective control to the most important routes *i.e. those which* transfer the largest part of the dose. Progress may then follow a leap-frog pattern. Improvement in one respect will bring benefit, but only up to a certain level. At this point some other route is comparable to or now more important than that first attacked. If this can be attacked successfully further measures directed to the first route may again be beneficial.

Figure 2 illustrates these possibilities in a simplified way. If the air in the operating room is very dirty then a good positive pressure ventilation system will reduce the level of airborne contamination and may give clinical benefit. Further improvements in air cleanliness may then be useless, since the major part of the dose now arises from contact contamination or from autogenous sources. However, if the situation with regard to these can be improved, e.g. if their contribution is dropped to the levels marked II in the figure, then the introduction of an ultra-clean air system could further reduce the risk of infection. This looks simple in the illustration. Unfortunately we rarely or never know in practice where we are in relation to the contribution of the various routes in a given situation, and so we have to proceed by a system of rational guesswork. Many investigations have been carried out and many more will need to be performed.

It is, perhaps unexpectedly difficult to get unequivocal answers. The situations are usually complex and continually changing, and it is often difficult to assemble records from a sufficient number of comparable cases to achieve statistically significant results except in those, fortunately rather uncommon, situations where the infection rate is very high and the effectiveness of the procedure tested high also. For example to achieve a 90% likelihood of demonstrating the improvement at the .05 probability level a mere 54 cases equally divided between controls and test would suffice, if the original incidence of infection was 50% and the improved procedures reduced this by 90%. A more likely situation with an incidence of infection of 10% and an expected improvement of 30% would need nearly 2,000 cases in both the control and trial groups for the same expectation of achieving a significant result. These examples are derived from the formula

$$N \simeq 10^5 \cdot \frac{200-a}{\alpha \cdot a^2}$$

Where N is the number of observations required in both control and trial groups to have a 90% chance of demonstrating a difference at the 95% level of significance. α is the percentage incidence and a the percentage reduction. The latter number is very high and means that only a limited number of selected situations can be investigated. Studies with insufficient numbers of observations are not only of little value, they may easily be misleading. The numbers quoted are only the statistical requirement. Uncontrolled variables may confuse the results and the assumption of the statistics that the events are independent may be far from true, in view of the transmissible nature of infection and the secular variations in the degree of challenge presented by the potentially infecting organisms.

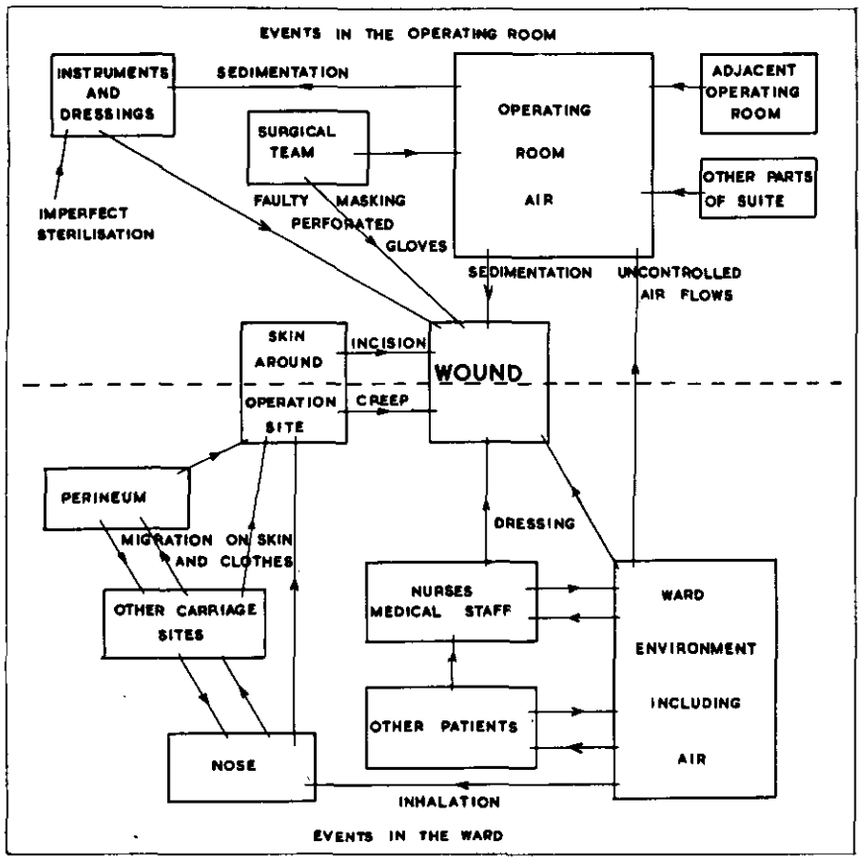


FIGURE 1. Routes of infection of a clean surgical wound. The routes shown by lines and arrows are only illustrative. They are not exhaustive nor has any attempt been made to indicate their relative importance.

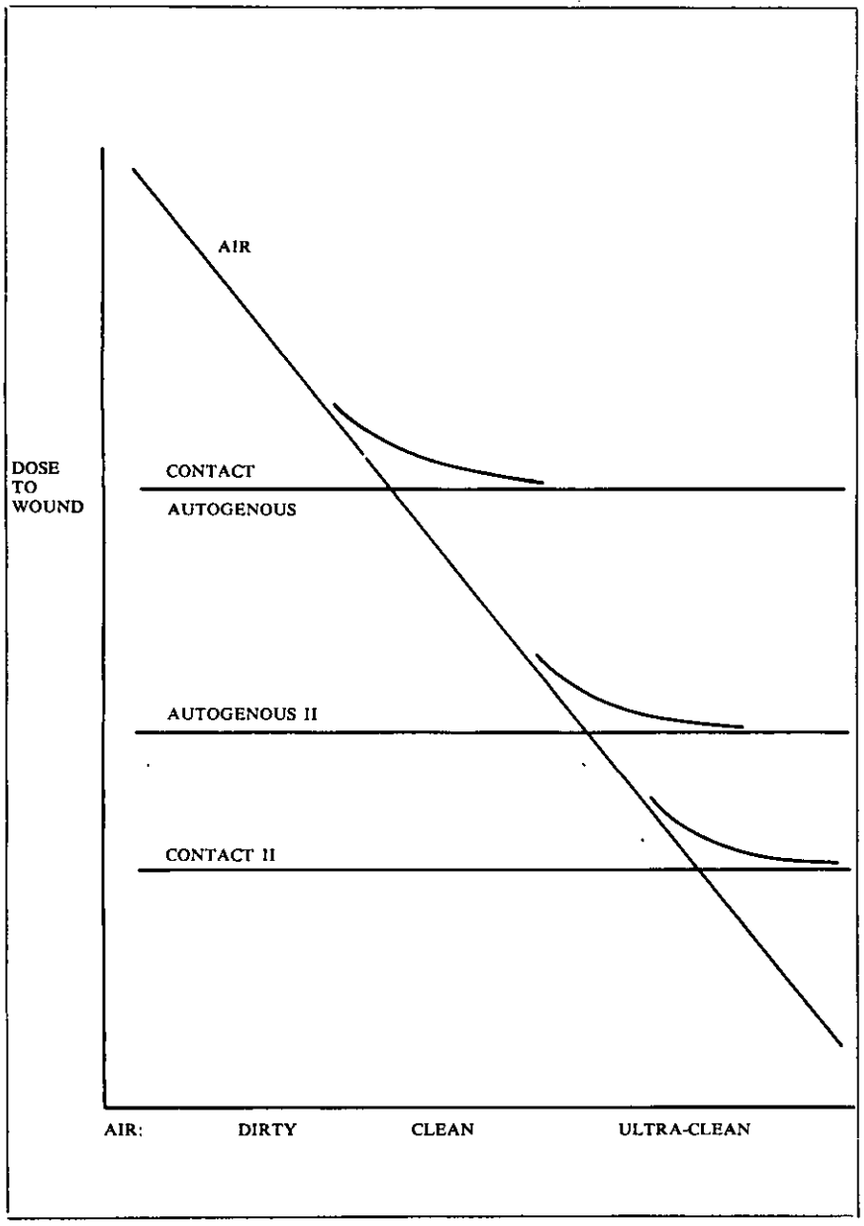


FIGURE 2. Sources of wound infection. The curved lines indicate the limitation due to the dose transferred by other routes on the effect of reducing the level of airborne contamination.

Attempts to control airborne transfer of infection

Within the hospital there are three particular areas where the use of better ventilation and air movement control has been used in the hope that this would lead to a reduced incidence of hospital-acquired infection.

1. **The surgical operating room**

Concern over airborne infection as a risk in surgical operations is almost as old as scientific microbiology itself. Lister, deducing from Pasteur's observations that micro-organisms from the air would contaminate the wound, set out to eliminate this route of infection. First by the use of carbolic acid in the wound itself, to kill any organisms that settled there and, subsequently, by attempting to sterilise the air in the neighbourhood by the use of a phenol spray. His success was dramatic and immediate. With an original mortality for limb amputations of about 50%, a series of fewer than 100 amputations in all demonstrated a reduction in the mortality to about 15% only. This took place a little over 100 years ago but at the end of his career Lister himself was doubtful as to whether the successes of his methods owed anything to their inspiration as ways of combating airborne infection. In 1890 he wrote ". . . it seems to follow that the floating particles of the air may be disregarded . . . provided we can . . . avoid the introduction into the wound of septic defilement from other sources" (*Lister 1890*). This uncertainty has continued unresolved to the present day. There are numerous recent reports of incidents where by far the most probable explanation of a series of wound infections is airborne dispersal from an identified carrier. These reports do not, however, establish the relative importance of this in relation to other routes of infection. It has, however, become generally accepted that positive pressure ventilation of the operating room with 0·7-1 m^3/sec. of clean air (1500-2000 cubic feet/minute) is desirable for general surgery (*Ventilation in operation Suites 1972*). With this proviso the level of air contamination will usually lie between 100 and 300 bacteria carrying particles per m^3 (3-10/cubic foot) and the present debate is centred around the question as to whether, or in what circumstances, further reduction in the level of airborne contamination may be beneficial. With modern ventilation techniques it is not difficult to achieve further reductions of 100 fold or even more. Evidence has been published showing substantial reductions in the rates for deep infections following total hip joint replacement operations concommitant with reductions in the levels of air contamination of this order (*Charnley 1972*) and further large scale studies in the field are at present in progress.

2. **General ward areas**

Strong advocacy of the need for good ventilation in the patient wards in order to combat the risks of infection has a long history. Many old hospitals witness to the way in which this was influential in determining the building design. The cruciform plans of some infectious disease hospitals, with the patient rooms opening off covered ways open to the outside air, and the extensive mechanical ventilation system of the Royal Victoria Infirmary, Belfast are good examples of this. However, perhaps even more than in

the case of the operating room, conclusive evidence is lacking. When St. Alphage Hospital, Greenwich was reconstructed recently to form the new District General Hospital a deep plan building was chosen in order to provide sufficient accommodation on a limited site, without the communication problems of a high rise structure. This necessitated full air-conditioning in order to control ambient conditions. It was then possible to design the air-flows so as to minimise airborne transfer between patient rooms. The lay-out of a section of the uppermost floor is shown in detail in *Figure 3*.

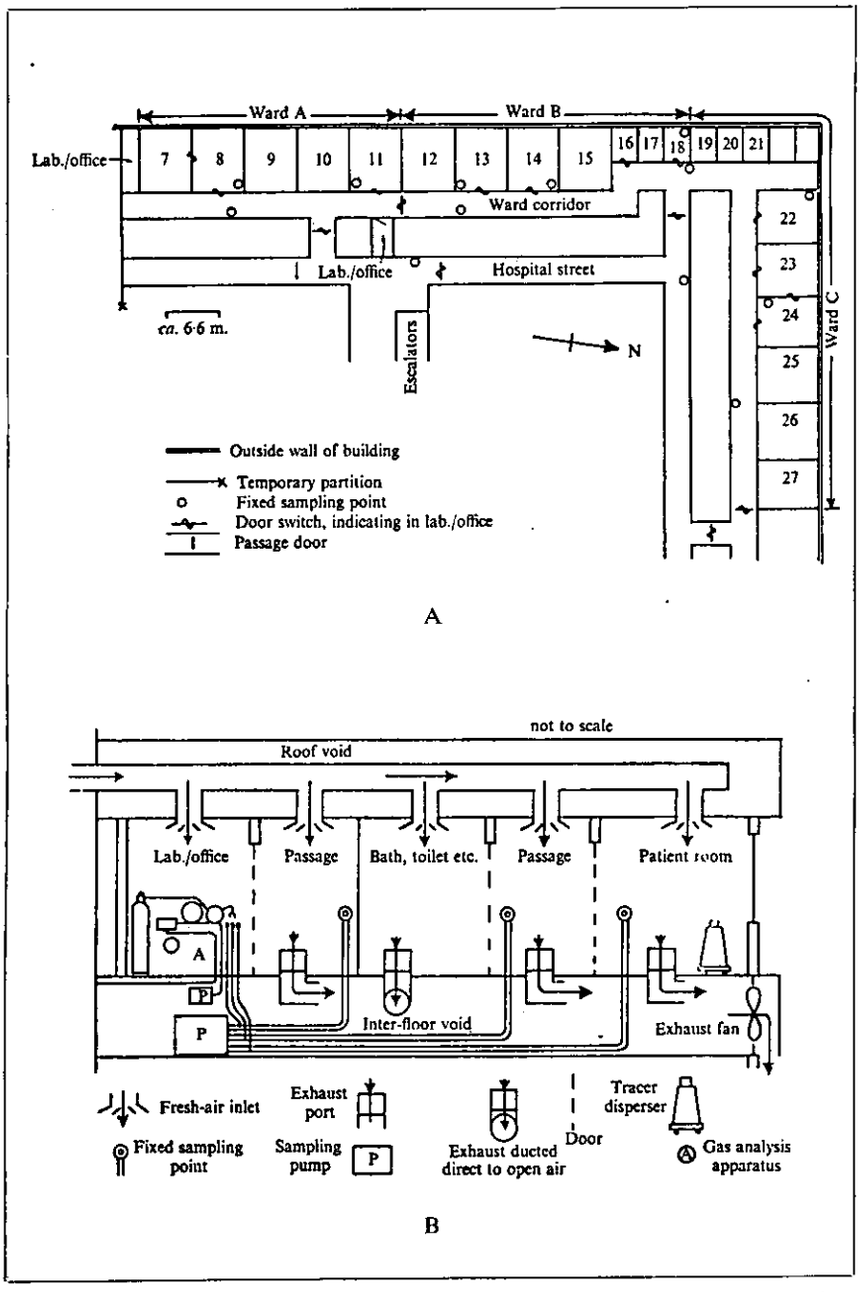


FIGURE 3. Ventilation in a fully air-conditioned hospital. (a) Plan of part of the medical ward floor. Rooms 7-11, 12-15 and 22-27 had six beds each. Rooms 16-21 were single bed rooms.
The sampling points and door switches were installed as part of the investigation of the effect of the ventilation on the transfer of airborne contamination within the hospital.
(b) Section of the medical ward floor showing the ventilation system and the experimental dispersal and sampling arrangements.

The original design intention was that the air supply to the corridor should result in a small inflow from this into all the patient rooms to prevent contamination dispersed within them from leaking into the corridor and so reaching other rooms. Owing to unexpectedly high resistance in the exhaust ports leading from the patient rooms into the inter-floor voids there was, initially, a substantial outflow from most of the patient rooms into the corridor. This was, in fact, an advantage from the point of view of a study of the effectiveness of the system in preventing airborne transfer (*Foord & Lidwell, 1975; Lidwell, 1975; Lidwell* et al *1975*). The substantial outflow velocities provided a better degree of isolation than would have been given by the original design (so long as the system is consistent i.e. the flow between rooms and corridor is in the same direction everywhere, the degree of isolation is the same whatever the direction of air flow may be). At a later stage it was possible to adjust the air supply-exhaust relationship so as to obtain a near balance between rooms and the corridor. Air movements were studied by using tracer gases. The consequent airborne particle transfers were determined with an inert particle tracer. Bacteriological observations made it possible to show the movement of identifiable strains of *Staph. aureus* from known sources in the patient rooms into other rooms and to record the acquisition of new strains of this organism by the patients.

The results of the investigation are summarised in *Figure 4*. The lowest two lines show that airborne particle transfer between patient rooms was very low and was correlated with the volume of air flow through the doorways. The apparent transfer of airborne *Staph. aureus* was, however, many times greater than that of the tracer particles and showed no correlation with air flow or the extent of particle transfer. It is not surprising in view of this that the rates of nasal acquisition were also uncorrelated with the extent of particle transfer and showed no significant difference from experience in open or only visually subdivided wards where there was no control over direct airborne transfer between the patients, *Table 1*.

This leads inevitably to the conclusion that the micro-organisms were

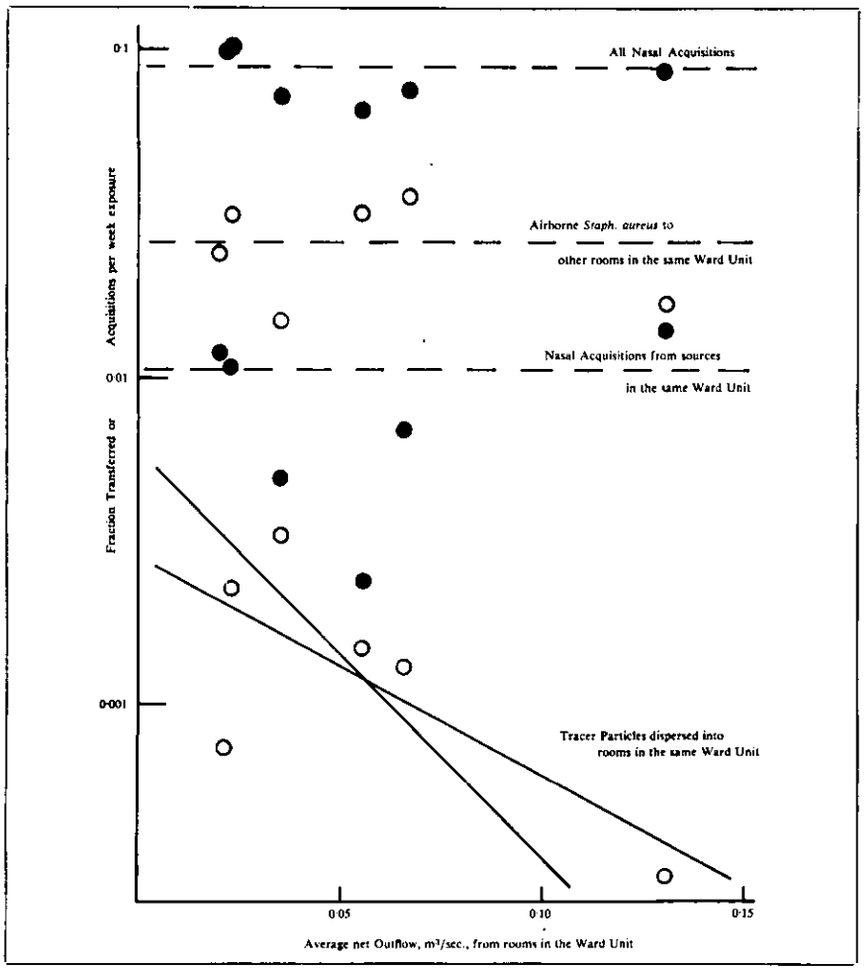


FIGURE 4. Nasal acquisition and particle transfer in an air-conditioned hospital. The lowest group of open circles show the observed fraction of the concentration of tracer particles in the source room found in other rooms of the same ward unit. The full lines are the two regression lines.

The upper group of open circles give the corresponding figures for airborne particles carrying Staph. aureus *dispersed by patient carriers.*
The upper filled circles give the rates of nasal acquisition of Staph. aureus *(fraction of patients acquiring a new strain per week of exposure).*

The lower filled circles give the corresponding figures for the acquisition from patient sources in the same ward unit only.

Table I **Effect of Structure and Ventilation on Nasal Acquisition of Staphylococcus Aureus**

	Hospital		
	A	B	C
	Open ward, 22 beds	4-bed bays	6-bed rooms
Ventilation	*Natural*	*Natural*	*Air conditioned*
Airborne *Staph. aureus*,/100m² min	204	89	280
Nasal acquisition rate,/1000 patient weeks	91	77	84
% from patient in other rooms or bays	—	54	53

Lidwell et al., *1975*

being transferred by some other route so that control of the direct air route is without effect (*cp — Figure 2*). Information from other investigations (see below) suggests that the nurses' dresses become contaminated when they look after patients, and that this contamination is redispersed when they work in other rooms. Only if transfer by this, and perhaps other, direct and indirect contact routes can be reduced, will control of direct airborne transfer by, say, ventilation have any beneficial effect.

Other studies carried out to compare mechanically ventilated subdivided wards with open wards having only natural ventilation have given varied results. At Aberdeen (*Smylie* et al. *1971*) a drop in sepsis followed a move into a race-track type ward which had positive ventilation of the patients' rooms, most of which were single bed units. In Glasgow (*Whyte* et al. *1969*) no difference was detected in simultaneous observations made in a mechanically ventilated subdivided ward and naturally ventilated open wards.

3. Patient Isolation

There is no dispute as to the need for isolation both of highly susceptible patients, for their own protection from the risks of infection, and of patients suffering from or carrying strains of micro-organisms likely to be dangerous to others. Susceptible patients are, of course, likely to become infected so that isolation units for such patients must also provide for containment when this occurs.

There is no inherent difficulty in providing ventilation arrangements which will reduce direct airborne transfer to almost any desired extent. It is not, however, so easy to decide what is the appropriate level for a particular situation. *Figure 5* shows three possible basic arrangements. No. 1a is the simplest, with extract ventilation for the containment of dispersal from an infective patient. No heating of the air is needed and mechanical reliability is high. 1b shows the reverse arrangement, with supply air, to protect a susceptible individual. This air must be warmed when necessary. Both need sufficient air flow through the door to prevent leakage in the opposite direction. There is a single barrier only against direct airborne transfer between any pair of rooms. The large flows

through the doorways, or around the doors when these are closed, result either in any escape from a room being actively drawn into all the other rooms, or in any air contamination produced within a room being positively discharged into the corridor. These effects can be greatly reduced and the degree of air isolation correspondingly improved, if, when the doors are closed, the bulk of the ventilated air passes through relief ports instead of being drawn from, or discharged into, the corridor, see *Table II*. To achieve this the doors must be close fitting. The addition of a lobby to the room, *Figure 5 II*, can have a comparable effect since only a comparatively small air flow is needed to prevent exchange across a closed door and, with a lobby, only one door need be opened at a time. The lobby also has other advantages by making it easier to maintain better contact isolation. If this lobby is ventilated then a really dramatic improvement in the degree of air isolation between rooms is obtainable. The lobby is now a barrier to air transfer in *both* directions so that there are now two barriers against air transfer between any pair of rooms.

Some other desirable features in the design of isolation rooms may usefully be mentioned here. First, isolation should not resemble solitary confinement. While excessive noise is a frequent cause of complaint in hospital, complete isolation from any audible or visual indications of life outside imposes great psychological stress. Direct vision into the corridor also reduces the number of times it is necessary for nurses and others to enter the room, particularly if the window to the corridor is either of stressed plastic or contains a speaking panel. Reduction in the frequency of entering and leaving the room is a major contribution to improving the degree of isolation both as regards direct air transfer and for most other routes of infection. The installation of pass-through hatches is a further help in this direction.

What are the results in practice? *Table III* shows the findings in a unit for burned patients comprising patient rooms with ventilated lobbies. First it will be seen that, when the room and lobby ventilation was as designed, the degree of isolation between patient rooms against direct airborne transfer, as measured by a particle tracer, was

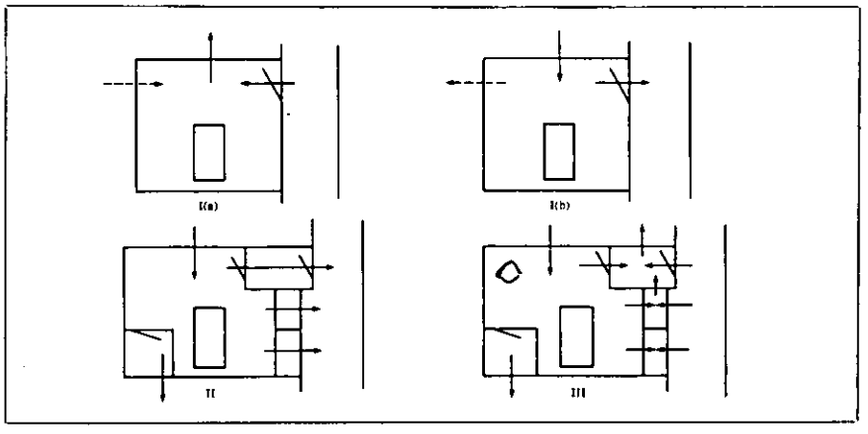


FIGURE 5. Ventilation of isolation rooms.

I(a). Simple extract for containment isolation only.

I(b). Input for patient protection only. The full arrows show the direction of air supply and of the flow between the room and the corridor. The broken arrows show flow through relief ports (if provided) when the door is shut.

II. Input and extract with lobby, W.C. and pass through hatches for supplies. As shown there is a net outflow *suitable for protective isolation. With a net* inflow *the system would be appropriate for containment isolation.*

III. Isolation room with ventilated lobby.

All four examples have a window and speech panel in the partition between the room and the corridor.

Table II Effectiveness of Isolation Room Ventilation
(10 Single-bed rooms in unit)

Ventilation System	Ventilation Supply Volume *(m^3/sec)**	Room-Corridor flows *(m^3/sec)*	*Index*
None or small balanced			
Doors *always* closed	—	0·004/0·004	250
Doors usually open	—	0·15/0·15	4
Simple Input or Extract	0·1-0·25	0·1-0·25/0·0014	100
With relief ports	0·1-0·25	0·03/0·0014	500
With lobby	0.05	0·05/0·0006	500
Ventilated Air Lock	0·1 Input 0·05 Extract 0·1 Lobby Extract	0·0006/0·0006	25,000

Index = reduction in airborne particle transfer in a 10 bed unit compared with open ward. 6-8 Entries/Exits to each room per hour. *Outward/Inward for input systems; Inward/Outward for extract systems.

Figures calculated by the method described by *Lidwell (1972)*

Table III Performance of an Isolation Unit

	calc.	observed *tracer particles*	Staph. aureus
Index Ratio	25×10^3	—	—
Source room to Receiving	350×10^3	45(340)* $\times 10^3$	$0{\cdot}5\text{-}2 \times 10^3$
Source room to Passage	$1{\cdot}5 \times 10^3$	290	125-250
Passage to Receiving	250	150	3-10
Per cent Infected	—	—	64
(In old accommodation)	—	—	82

*Values averaged for observed ventilation patterns
(in parenthesis value observed with ventilation correct)

Data from *Hambraeus and Sanderson, 1972* and *Hambraeus, 1973*

as high as theory would suggest. Frequent failures in this respect, however, led to an approximately eight-fold drop in the average level of isolation achieved. But, as in the Greenwich studies, the degree of bacterial transfer from infected patients was much greater than direct airborne transfer of the tracer. Most of this increase appeared to lie in much poorer performance in preventing intrusion into the receiving room, rather than leakage out from the room containing the source. In conformity with these observations there was little reduction in the infection rate compared with that found in the original simpler accommodation. In this unit it was possible to make a much more detailed study of the individual nursing procedures (*Hambraeus 1973*), and the results of this are exhibited in *Figure 6*. This shows the distribution of the numbers found in samples taken during a series of experimental runs. The sequence of events in each case was as follows. A nurse carried out a full nursing on a patient whose burn was infected with an identifiable strain of *Staph. aureus*. This occupied about 25 minutes. She then left the room, removed her gown, if any, and then took off her dress. This was then donned by an experimenter who also put on a clean gown over the dress, when specified, went into another room and carried out a full nursing procedure on a volunteer simulating a second patient. Contamination of the dress with the indicator organism was demonstrable even when a gown had been worn and the organism was dispersed into the air of the second room, or transferred to the bed and clothing of the second "patient", even when a clean gown was worn over the dress. Dispersal into the air of the source room during the single procedure was appreciably less than that detected routinely over a four-hour sampling period. This reflects other minor activities during the four-hour period and continuing dispersal by the patient throughout this time. Dispersal in the second room was much greater than the direct air-transfer of tracer particles, even if this is increased to allow for the possibility of very small particles with a much lower sedimentation rate than the tracer particles used. The dispersal was reduced when gowns were worn, especially if these were of a relatively impenetrable fabric. The level detected in four-hour routine samples were somewhat greater than that found from the experiments using gowns of balloon cloth (of the type used routinely), which is probably due to other minor activities during the four-hour period. However, none of the gowns reduced the dispersal to a level approaching that which could be caused by direct air transfer so that the effectiveness of the ventilation system was far from fully utilised.

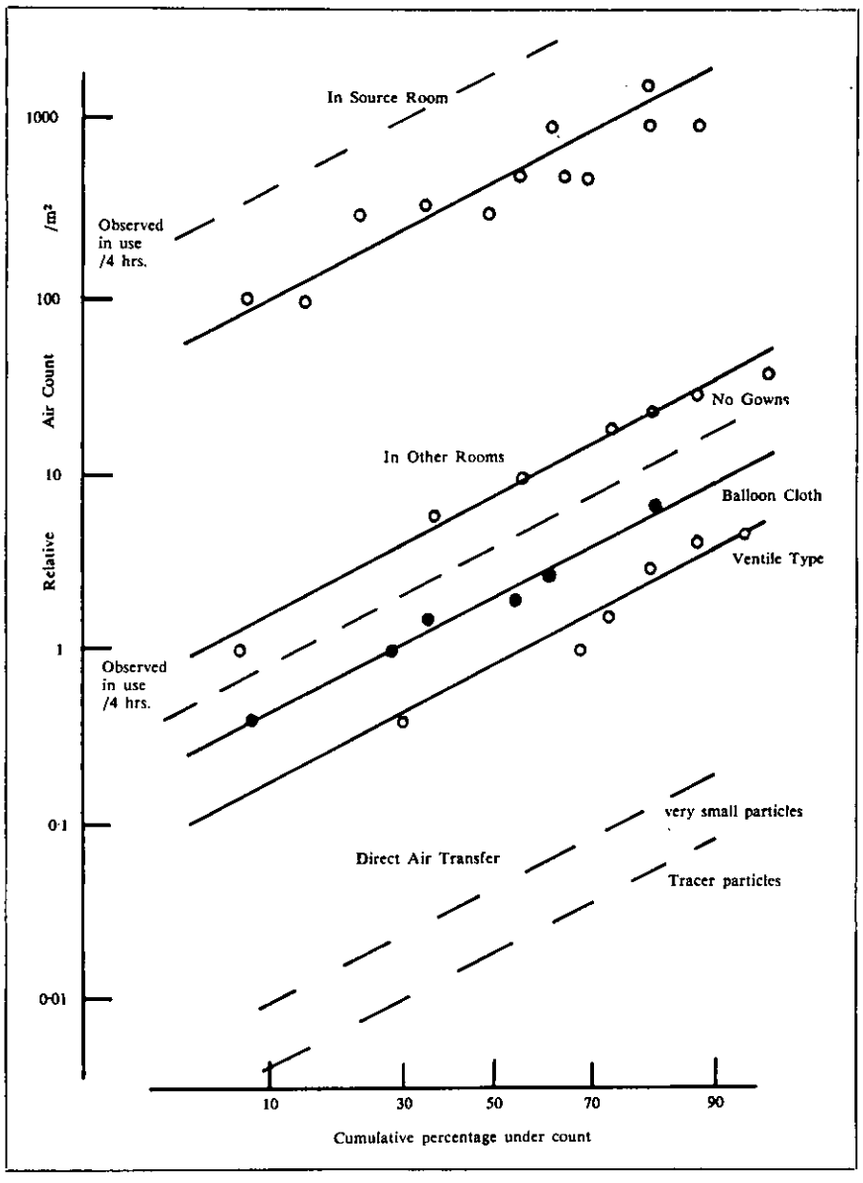


FIGURE 6. Dispersal of Staph. aureus *in an isolation unit during nursing procedures. The vertical scale shows the number of* Staph. aureus *colonies found on settle plates during the procedures. Details of the experiments are given in the text. The upper two broken lines show, for comparison, the number of colonies found on plates exposed routinely for four hours. The lower two broken lines show the results deduced from experiments with a particle tracer.*

Other methods for controlling airborne infection have been proposed. These include the use of plastic isolators, where the patient in his bed is enclosed in a large transparent plastic bag, fitted with glove ports and pass-through hatches to allow for nursing needs and with a filtered air supply. Such a system is also designed to eliminate most of the risk of transfer by contact. Another proposal is to provide air isolation for the individual bed by means of a circumscribing air curtain directed downwards from an

overhead canopy. Both these systems have been used to explore the relative contribution of airborne and contact infection in a burns unit (*Lowbury* et al. *1971*). Comparison was made between the experience of patients nursed in an open ward; in a bed enclosed within an air curtain; in a plastic isolator with the top removed so that the interior was in direct communication with the air of the room; in a plastic isolator with no filters in the air supply; and in a complete plastic isolator with filtered air supply. In the open ward the patients were exposed to the usual risks of infection by airborne and by contact routes. In the air-curtain bed the exposure to airborne contamination was reduced five to ten fold, see *Table IV*, but opportunities for contact infection were unaffected. In the plastic isolator with open top there was little reduction in the exposure to airborne contamination but considerable protection from contact transfer. In the complete isolator exposure to airborne contamination was reduced by 100 fold or more and there was good protection against contact transfer. The results of the experiments are shown in *Table V*. Compared with the open ward the air curtain gave no detectable advantage in any respect. In the open top plastic isolator there was a dramatic drop in infection from *Pseudomonas* but no effect on nasal colonisation or wound infection with *Staph. aureus* or other species of micro-organisms. In the complete isolator, in addition to the reduction in infection with *Pseudomonas*, there was also some reduction in nasal acquisition of *Staph. aureus* and, possibly, in the colonisation of burns with this organism. These results would indicate that infection by direct contact is the predominant route as regards infection with *Pseudomonas*. Control of *Staph. aureus* infection on the other hand demands either a greater reduction in the level of airborne contamination than that given by the air curtain bed, or control of both airborne and contact routes. The latter seems the more likely since even in the complete plastic isolator there was still an appreciable risk of colonisation with this organism.

A third study of patient isolation, for very highly susceptible patients receiving bone-marrow transplants, illustrates the failure to obtain clinical benefit even after apparently effective measures against airborne and contact transfer of infection have been instituted (*Vossen and Waay, 1972*). These patients were nursed in a "laminar flow" type of isolator with nursing procedures carried out through glove ports in the plastic side walls. The results are shown in *Table VI*. It will be seen that those patients who were nursed in the isolator received very effective protection against colonisation and clinical infection with exogenous organisms. This could not however prevent colonisation with endogenous strains, i.e. strains carried by the patient before admission into the isolator. Although infections due to these appeared to be fewer, which may have been due to reduced opportunities for infection with such strains in the absence of infection with exogenous strains, the majority of the patients died whatever the conditions in which they were nursed. In this situation no degree of environmental control of air or contact routes is sufficient to give any clinical benefit. This is dependent on finding some means for reducing the risks of autogenous infection (cp. *Figure 2*), either by improving the body resistance or by effective antimicrobial therapy.

Table IV **Control of air contamination in a Burns Unit**

System	*Relative contamination level*
Open Ward	100
Air Curtain Bed	10-20
Plastic Isolator	
Open Top	30*
No Filters	2
Coarse Filters Only	1
Full Air Filtration	0.2

*Isolator placed in a cubicle, not in the open ward

Data from *Lowbury* et al., *1971*

Table V **Infection in a Burns Unit**

	Nasal acquisition	*Colonisation of Burns*		
System	MR *Staph. aureus**	SA†	Pseudomonas	Other organisms
Open Ward	1	1	1	1
Air Curtain Bed	1·7	1.0	1.0	1.6
Plastic Isolator				
Open Top	1.0	1.75	*0·0*	1.2
Air Supply (all conditions)	*0·4-0·65*	0.75	*0·17*	1.1

*MR, strains resistant to more than one antibiotic
†SA, *Staph. aureus*

Data from *Lowbury* et al., *1971*

Table VI **Isolation of patients receiving Bone-marrow transplants**

	In positive pressure	*In 'laminar' flow*
Endogenous micro-organisms		
Colonisations	30	28
Infections	16	4
Associated with death	6	0
Viruses ,, ,, ,,	1	2
Exogenous micro-organisms		
Colonisations	8	1
Infections	4	0
Associated with death	4	0
No. of patients	4	3
No. who died	3	2

Data from *Vossen and Waay, 1972*

Design realisation and performance monitoring

Even in a situation where ventilation or air-movement can produce a reduction in the exposure to airborne microbial contamination, and where the reduction is likely to give clinical benefit this benefit will not result, no matter how appropriate the design intention, unless the system functions in accordance with it. Instances of inadequate standards of engineering construction, not to mention design, are so common as to be more the "normal" than the exception. Reference has been made above to examples of this both in respect of an overall hospital ventilation scheme and an isolation unit where detailed investigations were carried out. In the first of these the investigation was planned in parallel with the construction so that there was a built-in check on the performance. In the isolation unit the faults were only discovered at all, as in most cases, when an independent scientific investigation was carried out. In this unit the directions of air flow between the patient rooms, the lobby and the corridor were found to be reversed in some way or other on nearly half of the occasions on which they were examined. This resulted in a nearly ten-fold reduction in the effectiveness of the air isolation, although this was without clinical effect in the actual situation.

The scandalous frequency of defects of these and other kinds in ventilation systems installed at very considerable cost will only be reduced to its proper low level by the application of tests of performance both on completion of a project before acceptance by the hospital, and by routine checks on this performance during subsequent use. Ventilation engineers as a whole have been almost entirely unconcerned with the development of suitable techniques for assessment and monitoring. On completion of a system it is essential to measure the actual volumes of air delivered. This generally implies some provision in the construction since it is often almost impossible and always very difficult to obtain reliable measurements from the delivery side of grilles and diffusers. It is highly desirable that this provision should include some form of continuous monitoring device apparent to the users of the facility. The commonly installed pressure gauges across filters are useless for this purpose and often misleading, since they react to a *combination* of air flow and filter resistance. Flap valves, permanently installed rotating vane anemometers, orifice plates or venturis are some of the devices that could be used.

Directions of air flow are commonly more important than the precise volumes, and therefore need direct monitoring. It is, of course variations in the relative volumes supplied which often lead to undesired changes in air flow direction, although inadequate insulation from the effects of wind pressures on the building may also be a cause. Flow directions are easily checked with smoke, remembering that flow directions may be reversed at the top and bottom of any aperture or passage, as a consequence of thermal differences. Some more permanently installable device is however called for. Since the maximum pressure difference that is usually acceptable, or needed, across a closed door is no more than 1 mm water gauge, simple manometers are not sufficiently sensitive. By the use of venturis as multiplying devices in conjunction with low pressure diaphragm switches, as used for example to control flue pressures in heating installations, it is possible to provide direct visual (or audible) warning of incorrect flow direction at a level of around 0.5-1 mm water gauge pressure difference. There is, however, a considerable need for the development of simple, cheap and reliable indicating devices so that direct indication of correct function can be presented to the user at all times. High levels of accuracy are not required.

Conclusion

It is clear that attempts to reduce infection by control of airborne contamination are often unsuccessful. In view of the discussion presented in the earlier parts of this paper this is not surprising. Only in certain situations will the airborne route be the most important, or even of comparable importance to the other possibilities. In order to make rational and economical use of our expertise in air control we have to assess the level of air contamination which will reduce transfer of infection by the airborne route to below that due to the other routes as we are able to control those. No advantage will be gained in reducing airborne transfer to less than, say, one tenth of transfer by other means. The assessment is not easy, and for the present we have to proceed by inference from a general understanding of the ways in which infection occurs and from the clues provided by the limited studies which have been done. The difficulties of carrying out conclusive investigations means that this situation is likely to persist for a long time.

REFERENCES

Charnley, J. (1972). Post-operative infection after total hip replacement. *Clinical Orthopaedics and Related Research, 87,* 167.

Foord, N. and Lidwell, O. M. (1975). Airborne Infection in a fully air-conditioned hospital.
I. Air transfer between rooms. *J.Hyg. Camb. 75,* 15.
II. Transfer of airborne particles between rooms ibid. p.31.

Hambraeus, A. (1973). Transfer of *Staphylococcus aureus* via nurses' uniforms. *J.Hyg. Camb. 71,* 799.

Hambraeus, A. and Sanderson, H. F. (1972). The control by ventilation of airborne bacterial transfer between patients and its assessment by means of a particle tracer. III. Studies with an airborne-particle tracer in an isolation ward for burned patients. *J.Hyg.Camb. 70,* 299.

Lidwell, O. M. (1972). The control by ventilation of airborne bacterial transfer between patients and its assessment by means of a particle tracer. II. Ventilation in sub-divided isolation units. *J.Hyg.Camb. 70,* 287.

Lidwell, O.M. (1975). Airborne Infection in a fully air-conditioned hospital. III. Transport of gaseous and airborne particulate material along ventilated passageways. *J.Hyg. Camb. 75,* 45.

Lidwell, O. M., Brock, B., Shooter, R. A., Cooke, E. and Thomas, G. E. (1975). Airborne Infections in a fully air-conditioned hospital. *J.Hyg.Camb.* 72, 445.

Lister, J. (1890). *British Medical Journal* ii. 377.

Lowbury, E. J., Babb, J. R. and Ford, P. M. (1971). Protective isolation in a burns unit: the use of plastic isolators and air curtains. *J.Hyg.Camb. 69,* 529.

Smylie, H. G., Davidson, A. I. G., Macdonald, A. and Smith, G. (1971). Ward design in relation to post-operative wound infection: part 1. *British Medical Journal.* 1, 67.

Ventilation in Operation Suites (1972). Report published by DHSS, Chairman *O. M. Lidwell.*

Vossen, S. M. and Waay, D. van der (1972). Reverse Isolation in Bone Marrow Transplantation. *European Journal of Clinical and Biological Research* XVII I p.457, II p.564.

This article is based on a paper originally given by Mr. Howorth, President of the Institute, at the symposium held in London on June 23, 1976. Mr. Howorth describes the results of a survey carried out by Howorth Surgicair in three operating theatres.

Howorth Surgicair would like to thank Doctor G. E. Hale-Enderby and Doctor David Enderby for their invaluable help and advice, also Doctor E. Kershaw for his assistance in carrying out the tests at the hospitals concerned.

The Control of Anaesthetic Gas Pollution

F. H. HOWORTH, FRSA FInstPI FIIC PIHospE

A maximum acceptable level of pollution of ambient air by anaesthetic gases for regular inhalation by members of the theatre staff and surgeons, as well as members of the nursing staff, has been set by the Federal Government of the United States of America at 30 ppm. This is shortly to become mandatory together with monitoring equipment providing alarm systems, if that level is exceeded.

Much has been said and published about the hazards of regularly inhaling low concentrations of anaesthetic gases, and certainly no one working in these environments should be expected to expose themselves to such health risks.

Howorth Surgicair carried out a survey of three operating theatres, each having a different type of ventilation, to determine the level of pollution by N_2O. A Miran 101 portable I.R. Specific Vapour Analyser with a scale reading from 0-250 ppm was used. This equipment has a claimed accuracy over this range of 0·027 ppm.

The areas where the concentration of anaesthetic gases have been measured and found to be above acceptable level are:

(1) the area around the anaesthetic machine;
(2) the area around the face of the patient;
(3) the anaesthesia Induction Room;
(4) the Operating Room;
(5) the Recovery Room;
(6) the Intensive Care Unit when it is used for recovery from anaesthesia.

In some cases the N_2O concentration was more than ten times the acceptable level.

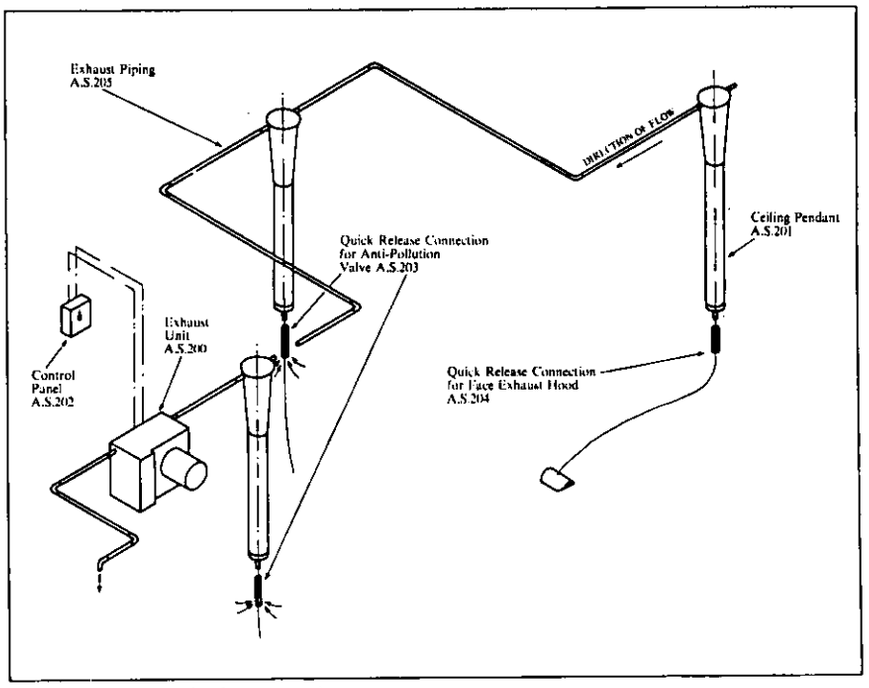


FIGURE 1: Typical scavenging system.
© Howorth Air Engineering Ltd., 1976.

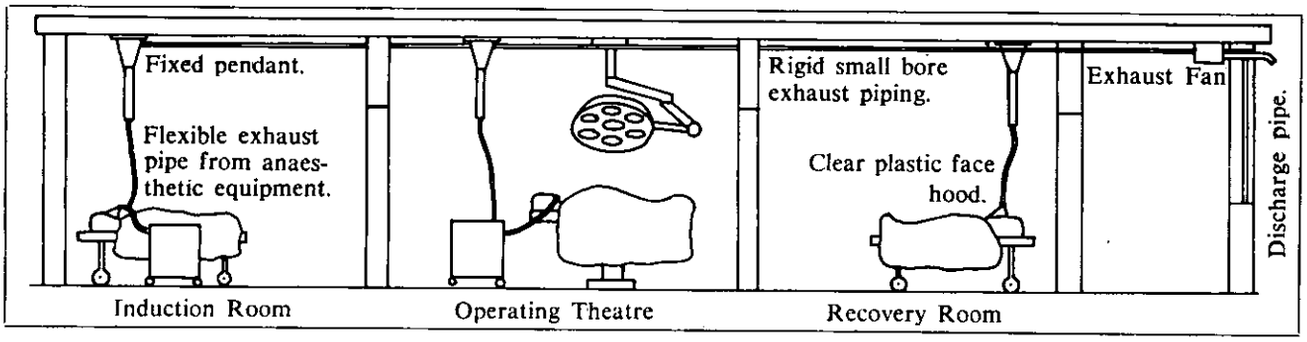


FIGURE 2.

Patients Exhaled Breath-Gas Concentration N_2O

It is a recorded and accepted fact that a patient under anaesthetic for a period of one hour has a total volume of gas in the body of approximately 20-30 litres. Ninety per cent of this will be exhaled within ten minutes of being disconnected from the anaesthetic machine, and during this period a maximum concentration of exhaled gas would reach approximately ten per cent of the volume of exhaled breath even though it would be for only a very short period and the decay would then be rapid. Peak would, therefore, be 100,000 ppm decaying rapidly to between 200 and 300 after one hour. No published work is available to ascertain the decay curve after this.

Typical Examples

Hospital 1

Hot day. August 14, 1975. Air conditioning working, distributing air from the ceiling.
Start at 8.45 am = zero N_2O.
Start + 45 mins after entry of patient 225 ppm with a radius of 4ft from the anaesthetic machine.
Start + 1 hour 15 mins, the level was estimated (by speed of deflection of the meter) to be in the order of 400 ppm.
The corridor outside the theatre had 35 ppm.
In this case Induction Room and Recovery Room had all the windows open because of the hot weather, even so, readings of 30 ppm were recorded.

Hospital 2

Cool day. October 6, 1975. Air conditioning working at 20 air changes per hour.
Start at 8.20 am = zero N_2O.
Start + 15 mins, 50 ppm
Start + 30 mins, 120 ppm
(N_2O flow rate 2 litres/min using a passive scavenging valve).
Start + 40 mins, above 250 ppm with normal expiratory valve.

In the Recovery Room which is large and open-planned with 11 patients recovering, there were 40 ppm $\pm$ 2 ppm measured in 12 different positions including the Nurses' Station.
The Induction Room is of large size with four positions for anaesthetising. The general level varied from 150-200 ppm with peaks of estimated 400 ppm. These readings were taken with all doors open. The lowest reading that could be found anywhere in the room was 60 ppm.

Hospital 3

With the Charnley-Howorth Enclosure in the theatre and the air conditioning system working. Because of the downflow of 65ft/min there was complete dispersion of the gases. The level of N_2O out of the enclosure diffuser tubes was 60 ppm after one hour of use.

General Observations

The pollution levels in the operating theatres and induction rooms vary according to the anaesthetic circuits used. Some circuits contribute greater pollution than others, but all circuits have been found in our survey to cause pollution levels of a high order.

The Solution

In order to remove these gases adequately so that a level of 30 ppm is not exceeded, we have designed and produced an active scavenging system which is supplied in the form of a kit of parts for installation by the hospital engineering department, or if preferred, by ourselves.
The Howorth active scavenging system consists of a specially designed exhauster which will overcome the resistance of 60ft of main exhaust pipe as well as three branch junctions, pendular, rigid and flexible pipes etc.
The rigid pendant which is fixed to the upper section of the pendular pipes, i.e. from the ceiling down to 6ft 6ins above the floor in all three rooms, terminates in quick-fit connections with automatic valves, so that when one of the lower flexible pipes is removed the suction is automatically shut off at that point. These flexible pipes and connections are similar to those used on the Charnley-Howorth Body Exhaust System and are a well established product.

In the Induction Room and Operating Theatre the lower flexible pipes are fitted with a "no pressure" orifice valve so that only an indirect connection is made to the anti-pollution valves.

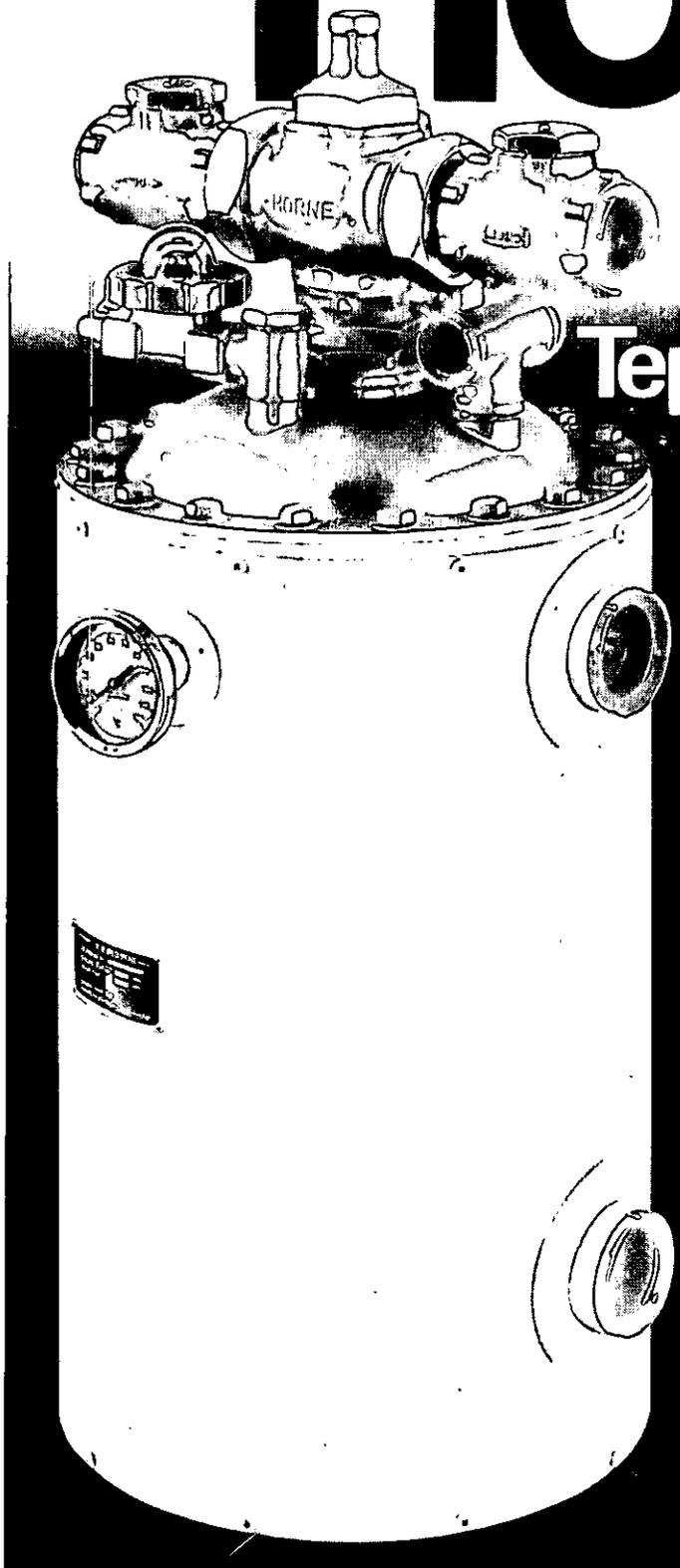
In the Recovery Room, the lower flexible exhaust tube connects directly to a face cone from which a much higher volume is exhausted.

It was felt that for a suite of theatres, a group of these systems would be preferable so that all parts would be standardised, and in the unlikely event of a fan motor failure then only one scavenging unit would be inoperative.

Survey

Howorth Surgicair are pleased to announce that they can now offer a complete survey of the areas which are likely to be polluted by an anaesthetic gas together with a detailed report on the survey and recommendation for reducing the concentrations to an acceptable level.

Horne



Tepidstat... a new approach to temperature control for warm water supplies

- TEPIDSTAT is an economical way of providing thermostatically mixed warm water to ten or more outlets
- TEPIDSTAT maintains temperature control from full flow to low flow at the outlets and during periods of no demand
- TEPIDSTAT has a concealed temperature adjustment and the temperature can only be altered by someone in authority
- TEPIDSTAT requires very little maintenance and is easily installed

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Mr. Shelton represents the Institute on a British Standards Institution Committee. This insight into the workings of such a committee will be of great interest to readers.

When the BSI meets.

J. C. SHELTON, FIHospE

One of the services rendered by the Institute is to provide members to sit on current B.S.I. Committees and as I am one of these sponsored to sit as a member of the B.S.I. Committee at present up-dating B.S.3970 on Hospital Sterilizers, I thought that other Hospital Engineers may be interested in knowing some of the workings of the Institution.

When a standard goes to press it embodies all the latest safeguards and requirements that the particular committee can offer, the time and endeavour spent on the various drafts and the meticulous attention to detail has to be seen to be believed. Despite this the Committee recognises that even as it sits it is possible that developments may be taking place somewhere in the world that will render all its carefully worded sentences and paragraphs out of date. It is because of this that the first rule of the Committee must be that the stipulations enclosed in the standard do not stifle progressive thinking.

The other criterion of course is that it must be thorough and it is to this end that long discussions take place on what may appear to be very minor points. Suggestions on some technical or editorial matter will criss-cross the table until the Chairman recognises and accepts what he feels to be the correct wording. To an outsider the point in question may not seem worthy of discussion by the eminent members present, but it is this attention to detail by the Committee that allows the intending customer to rest assured after quoting in his specification that the particular piece of equipment to be purchased must be to B.S. . . .

The B.S.I. Committee on Hospital Sterilizers on which the writer sits is quite large. On a good day there may be some 26 members present. The membership of the Committee is drawn from a wide range of interested parties. There are those concerned with the manufacture and sales of sterilizers and associated equipment, together with those interested in the end products that are sterilized. It is this balanced mix, all with a vested interest, and all with perfectly valid points of view to express, that leads to some of the lengthy discussions. I must emphasise that despite the fact that many members represent firms or organisations who could benefit from their membership, all meetings I have attended have been carried out with complete impartiality.

As one may imagine the Health & Safety at Work Act looms largely in the discussions, and therefore the member representing this body is a well-known voice. A worthwhile point that he brought to the last Committee and one that was again discussed at length, was a requirement that sterilizers with multi-locking screws or clamps holding the door must have one that partially opens the door as it is being unscrewed, preferably sited opposite the hinge, thus slowly but positively venting to atmosphere as the locks are unscrewed.

Before the final copy goes to print it will have been preceded by many drafts, prepared by Sub-committees formed from the members of the main Committee. When the draft has been prepared a copy is submitted to each member of the full Committee for him to study. The draft is then read out line by line during subsequent Committee Meetings and subjected to a minute scrutiny. Eventually when the official draft has been completed and the full Committee are satisfied that a unit produced to this standard will not only sterilize goods correctly, but will also be safe to operate, and that the standard itself will not stifle development or preclude any manufacturer from using his own engineering techniques, it will then be submitted to the B.S.I. for editorial.

Another problem that the Committee is faced with is knowing where to stop. The sterilization of dressings, instruments and fluids etc. requires more than just the sterilizing vehicle itself. There is also the question of containers for the goods being sterilized, and here the Committee members had differing views. Some felt that containers for bottled fluids etc. should be dealt with under a separate standard, while others took the view that they are all part and parcel of the sterilizing unit. It has been decided that a separate Sub-committee should look into this problem.

In particular the question of containers for bottled fluids is a difficult one, and the "perfect container" or even a "near perfect" one has yet to be found. Some time ago the B.S.I. held a day's conference with all interested parties being invited to discuss this problem. Many new manufacturing techniques and products were discussed, and many disturbing facts were brought to light in the existing methods of containing fluids, particularly regarding the enclosures or seals.

When one considers it, the poor bottle of fluid has quite a bit to put up with during sterilization. From start to finish the sterilizing cycle is one whole series of reversals. First the bottle is dropped into a crate and shut into a dark autoclave, where, depending on the authority, it may start by being subjected to a vacuum. The cap and seal must stop the fluid being pulled out of the bottle, or the bottle itself exploding. If it endures this it is then squirted with steam, which not only exerts a temporary unequal pressure on the outside of the bottle and enclosure, but also a temperature as well. During this phase the cap and seal, which will have a different co-efficient of expansion to the bottle, must prevent the ingress of steam, and the bottle itself will have to withstand the pressure.

Shortly after reaching a balanced state of temperature and pressure it is decided that it must return to its original condition, but not in its own good time, that would take too long, so to achieve this in as short a time as possible the bottle may now be squirted with water at an ever-decreasing temperature. By adjusting the laws of cooling, the bottle and its contents are decreased to a temperature of 80°C much quicker than would normally happen. So doing will again put the bottle and its enclosure under stress. Therefore, providing that the bottle and enclosure were in good order, that the sterilization achieves its time-at-temperature, and the integrity of the enclosure is maintained, providing also that the contents are poured correctly from the bottle, the end result should be perfect. B.S.I. No. 3970 will have gone a long way in ensuring that this is so.

Product News

New Filters with 12-month guarantee

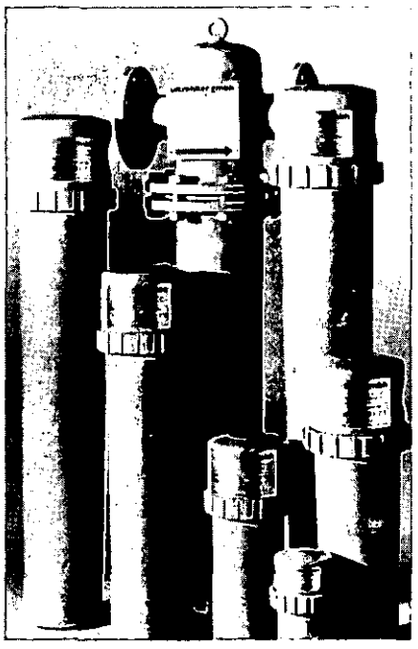
A completely redesigned range of high efficiency filters, rationalised to match the internationally accepted standard outputs of power units such as compressors, motors and pumps, has been announced by Ultrafilter GmbH of Düsseldorf, W. Germany. The manufacturer believes they are the first in the world to be offered with a twelve month minimum service-life guarantee.

The new '76' series includes models for sterile filtration, for total removal of oil, water and dirt from air and gases, for fine filtration of liquids and steam, and for dust and odour removal.

Ultrafilter have completely redesigned the three main component parts of the filter — the medium, the element and the housing. The new design increases the effective depth of the units, thus giving greater contaminant-capacities and filtration efficiency. Service life of from one to three years (6,000-10,000 operating hours) is claimed.

Ultrafilter is a specialist company which manufactures, in addition to fine-filtration products, air and gas dryers matched to the output requirements of process systems.

Further information: *ULTRAFILTER GmbH, Heinrich-Heine-Allee 3, D-4000 Düsseldorf 1, W. Germany. Telephone: (0211) 329395. Telex: 8587851 uf-d.*



The composite filtration medium is faced on both sides with stainless-steel sleeves bonded to stainless-steel end-caps.

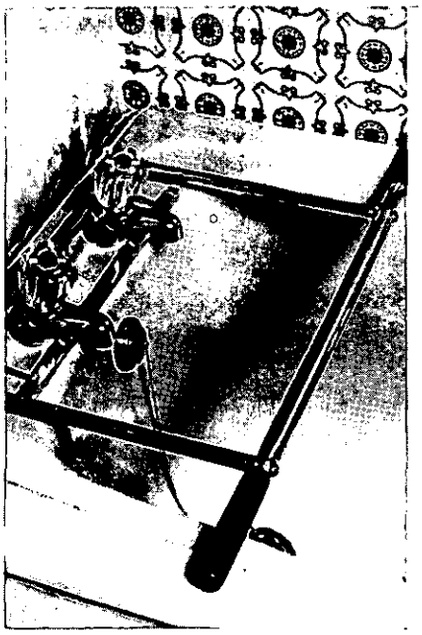
Low cost aids for the disabled

Two low cost aids for the elderly and disabled have been introduced by Kimberley-Bingham, the Midlands specialist invalids' aids company. The aids have been introduced in response to the expenditure cuts on hospital and rehabilitation equipment announced by the Government.

The first aid is a bath rail called Ezefit which fits over existing bath taps by tightening two wing nuts. It gives a firm hand hold while standing or sitting.

The second aid is known as the Fold-a-way grab rail. It features a folding design particularly suited to confined spaces. It can be used beside toilets, washbasins, showers, etc.

Further details from: *Kimberley-Bingham & Co. Ltd., 111 High Street, Bordesley, Birmingham B12 0JS. Telephone: 021-773 6166/7.*

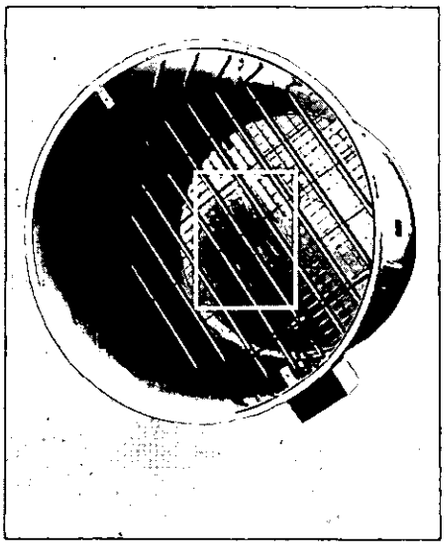


Air flow measurement system

A new measuring technique has been pioneered by Airflow Developments Limited. It is named Flow-Grid, and replaces orifice plates or pitot tubes in measuring the flow of air through ventilating and air-conditioning ducts. The new system is claimed to be more accurate over longer periods than pitot tubes, and not to cause the large duct pressure losses incurred by using orifice plates. The precise location of the grid is unimportant.

The grid consists of a length of circular section standard steel ducting containing vertically mounted tubes. The grid formation acts as a screen, smoothing out flow irregularities and making measurements easier. It also provides a permanent and accurate method of monitoring flow.

Further information: *Airflow Developments Limited, Lancaster Road, High Wycombe, Bucks. Telephone: 0494 25252.*



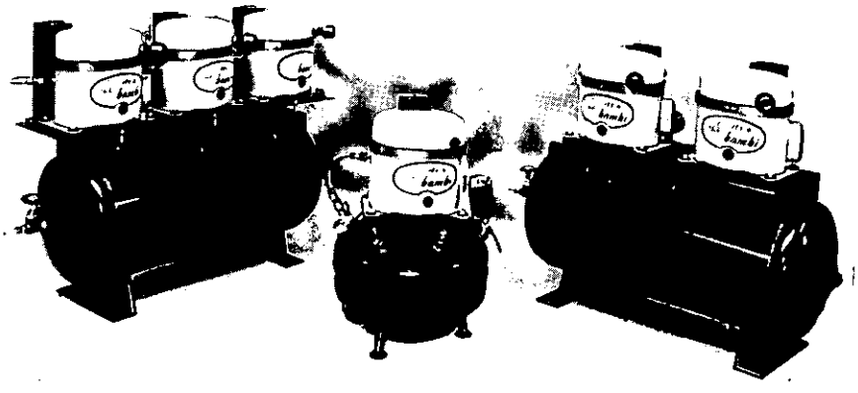
End view of a circular duct section containing a Flow-Grid. The area indicated by the white rectangle is shown enlarged in the other photograph.

New portable silent compressors by Bambi

A new range of portable air compressors has been introduced by Bambi Air Compressors, a new company set up in this country to manufacture this type of equipment, which has hitherto been imported from the Continent.

The Bambi range are compact, fully enclosed portable air compressors which are small and silent in operation. Five models are available, in single, twin and triplet packs. They range from the single Master, with a ½-hp motor, an air receiver capacity of 15 litres and weight of 60lbs, to the Major Triplet which is a 2½-hp unit with an air receiver capacity of 40 litres and weight of 210lbs. Units can be added when desired, and standard working pressure is 120 p.s.i.g. max. throughout.

Further information from: *Bambi Air Compressors, 47-57 Bishop Street, Birmingham, B5 6LT. Telephone: 021-622 5886.*



Packaged plant solves effluent problems

Davenport Engineering Limited have introduced an easily installed portable effluent treatment plant. The unit is able to cope with effluent created by a population of from 35 to 150, with flow rates of between 7·5 and 30 m^3/day. Higher flow rates can be accommodated by installing extra units in parallel or by using alternative designs.

All pipe work within the unit is factory fitted, to reduce to a minimum the cost of site installation, which need only take two or three days.

Further information from: *Davenport Engineering Limited, Harris Street, Bradford BD1 5JD. Telephone: Bradford 29361.*

Pollution-free anaesthesia system

A complete Pollution-Free Anaesthesia System which protects operating theatre staff from waste anaesthetic gases exhaled by the patient has

been developed by The Medishield Corporation. The system extracts excess gases directly from the anaesthesia machine, and ducts them away from the theatre.

The Medishield system extracts waste gases via an anti-pollution valve attached to the expiratory valve within the breathing circuit. The gases then flow through a corrugated hose to an autoclavable reservoir attached to the anaesthesia machine below the level of the patient. A feature of the reservoir is an audio device whose note varies with the patient's respiration rate.

The system can be employed in a number of configurations, using fixed or portable individual pumps, or sharing a pump in multi-theatre installations with a number of other anti-pollution units.

Further information: *BOC Medishield (for UK), or Medishield International Sales, both at 12 Priestley Way, London NW2. Tel. 01-452 6422.*

Modular mats

A new leaflet giving full details of the Cimex Modular System for Matador Mats and Matwell Frames is available. These units are manufactured of the same components as the established conventional made-to-measure Matador Entrance Mats, but is produced in one basic size of 600 mm by 800 mm. This is an international standard module, and enables mats to be installed in any configuration to fit all sizes of entrance.

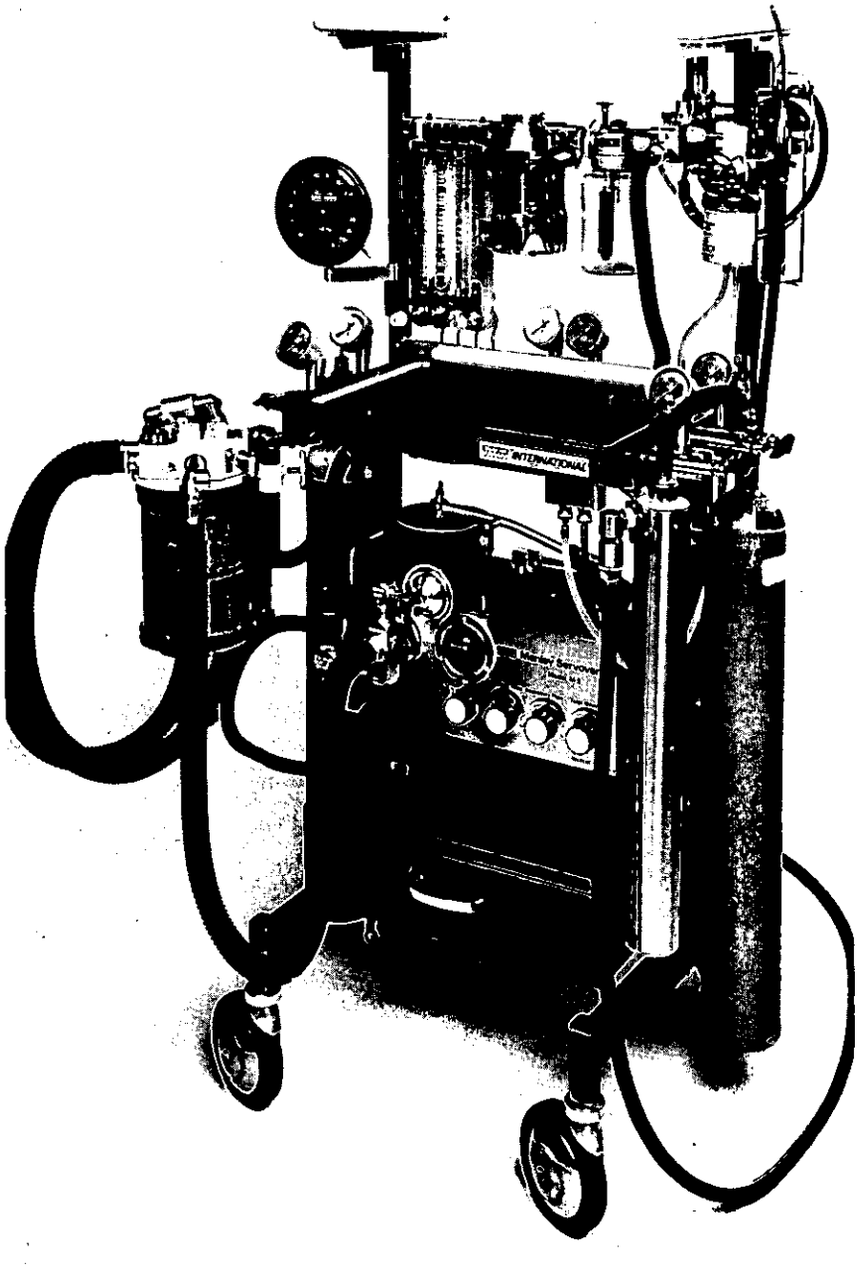
Copies of the leaflet are available from: *Cimex Limited, Matador Division, Millfield Road, Faversham, Kent ME13 8BX. Telephone: Faversham (079 582) 3220.*

Castor footbrake

Flexello Castors have introduced a new butterfly type of foot operated wheel brake for swivel castors. It is particularly suitable for hospital and catering equipment. The brake is available on the Flexello series 11 double ball bearing swivel castor, and can be added to castors of that series already in service.

Operation is simple and quick, requiring only slight pressure either side of the central cam to lock the brake on or off.

Further information: *Flexello Castors & Wheels Ltd., Bath Road, Slough, Bucks. SL1 4ED. Telephone: 0753 23841.*



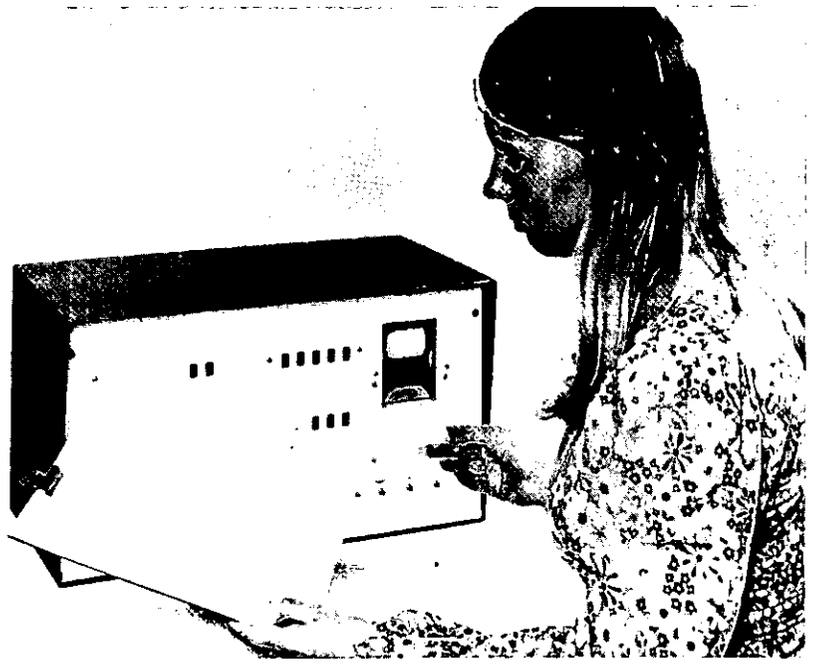
Boyle International anaesthetic table equipped with Medishield's new pollution-free anaesthesia system.

The Flexello Butterfly Foot Operated Wheel Brake.

Electronic weighing for hospital laundries

A new system of electronic weighing for use with hospital laundry monorail conveyor systems has recently been introduced by Futurail. The system avoids the use of platform scales and trolleys, the only previous means of measuring the amount of soiled work coming into the laundry, entailing double handling. An existing monorail system can have the unit fitted, by the incorporation of a section of special track.

A clear digital display shows the number of units which have passed through the equipment since it was last zeroed, and gives the individual and total accumulated weight. The print-out provides a written record, and the monitor unit can be placed at any convenient point remote from the laundry storage system if required.



The standard unit has a weight capacity up to 100kg, and is based on standardised components, and plug-in printed circuit boards. The cost is approximately £1,500 — about half the price of an equivalent platform scale with print-out facilities.

Futurail, Riverside Works, Cropredy, Banbury, Oxfordshire. 0295-75 444.

Clean-FLOW Quiet-DUCT silencer

The 'Clean-FLOW Quiet-DUCT' Silencer designed and manufactured for use in hospitals and other buildings by Industrial Acoustics Company, of Staines. Unlike other types of silencer, it has a perforated metal element face which cannot break down and create a potential health hazard in a hospital situation. Unit 16, Central Trading Estate, Staines, Middlesex.

New electronic hand-dryer

The all-British Horstman HS2000 hand-dryer is claimed to be far more economical than other forms of washroom hand-drying, including textile, cloth or paper towels.

The airflow in this new design is directed into an enclosed chamber so that the hot air is transferred to all parts of the hands. All delivered hot air is passed directly over a high temperature element, killing all bacteria.

Further information: *Haddock Horstman Limited, New Bryngwyn Rd., Newbridge, Gwent. 0495 243668.*

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Applicants should have a relevant degree, e.g. in Mechanical or Civil Engineering, and/or membership of a professional body, e.g. IMechE, IEE, ICE, IME, IMunE, or be qualified as a Surveyor, Architect, or Clerk of Works. Appointment will be in grade P & TO I, salary within scale £4,720-£5,930; supplement of £313.20 per annum also payable. Non-contributory superannuation scheme.
Further details and application forms from The Secretary, Glasshouse Crops Research Institute, Worthing Road, Rustington, Littlehampton, West Sussex BN16 3PU. Closing date 12th November.

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for the next issue to be published on

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BRIGHTON
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Applications are invited for the post of

HOSPITAL ENGINEER

Responsible to the District Engineer for the operation, maintenance and estate management at Brighton General, Bevendean and Lady Chichester Hospitals and other health care properties.

Applicants will have served an apprenticeship in mechanical or electrical engineering and must possess either HNC in mechanical or electrical engineering or equivalent C&G certificate or other approved qualifications.

Salary scale £3,615 to £4,140 per annum plus £291 per annum basic pay supplement, also £108 special responsibilities allowance.

Application forms and job description can be obtained from the District Personnel Officer, Brighton Health District, Brighton General Hospital, Elm Grove, Brighton, Sussex. Tel. Brighton 66155, and should be returned by 29th October, 1976.

South West Thames Regional Health Authority

Engineering Clerk of Works (2)

To work within the Engineering Division of the Authority. Applicants must have served an apprenticeship in mechanical or electrical engineering and have had not less than five years' experience supervising site installations employing trades associated with mechanical or electrical building services.

Salary scale: £3,345-£4,251 per annum plus £141 per annum London Weighting.

Commencing salary according to experience.

The appointment will be for the supervision of engineering work at various sites within the region, which covers the following area — Surrey, West Sussex and the south-west corner of London.

Initially the officers will be based at Guildford, but this could vary depending upon the location of the particular sites for which they are responsible.

Application forms from Personnel Officer (S2), 40 Eastbourne Terrace, Paddington W2 3QR.

Completed forms to be returned by 15th October.

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HOSPITAL ENGINEER

Responsible for the operation and maintenance of engineering and building works within a small sub-district of Hospitals based on Salisbury General Infirmary.

Salary scale: Basic £3,351-£3,942 plus £291 p.a. non-enhanceable pay award. A special responsibility allowance of £72 p.a. plus bonus 15% of basic is payable.

Application forms and job descriptions available from Personnel Department, Odstock Hospital, Salisbury, Wilts. Tel. Salisbury 6262, Ext. 419.

Further details available from District Works Officer at Odstock Hospital (telephone Ext. 417).

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