HOSPITAL ENGINEERING

March 1978

International Federation Issue

The Journal of the Institute of Hospital Engineering

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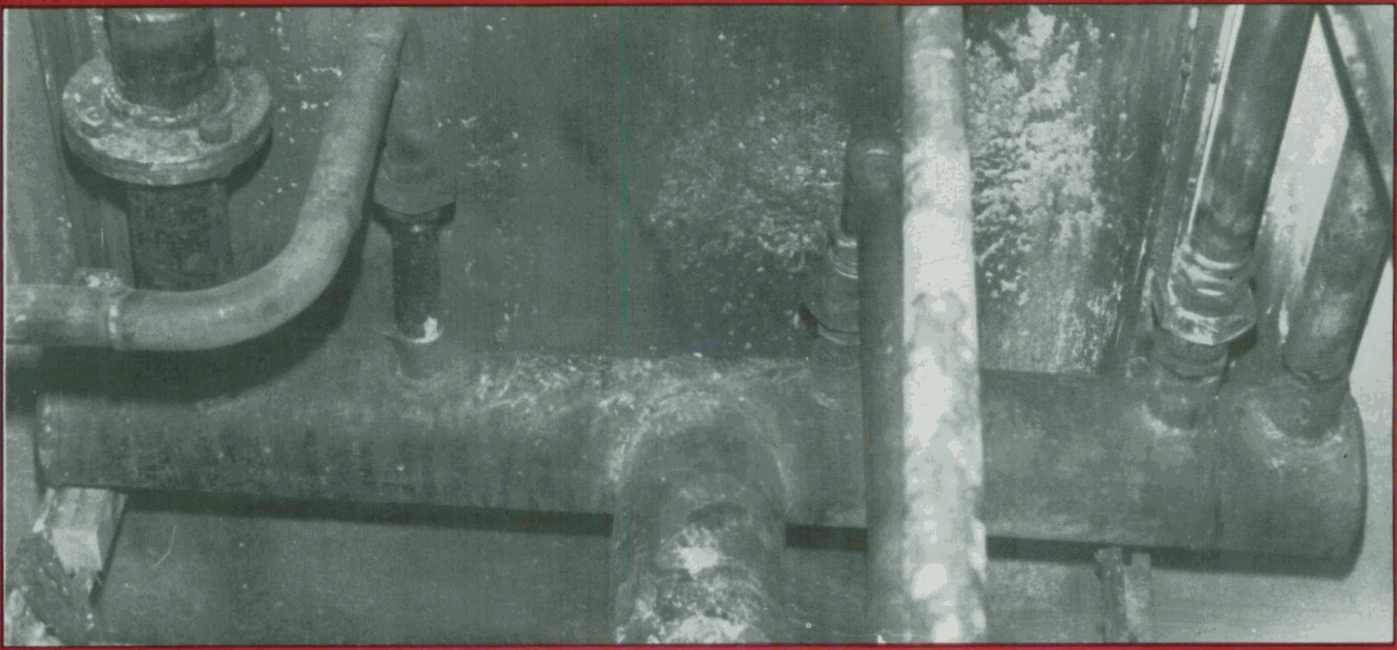
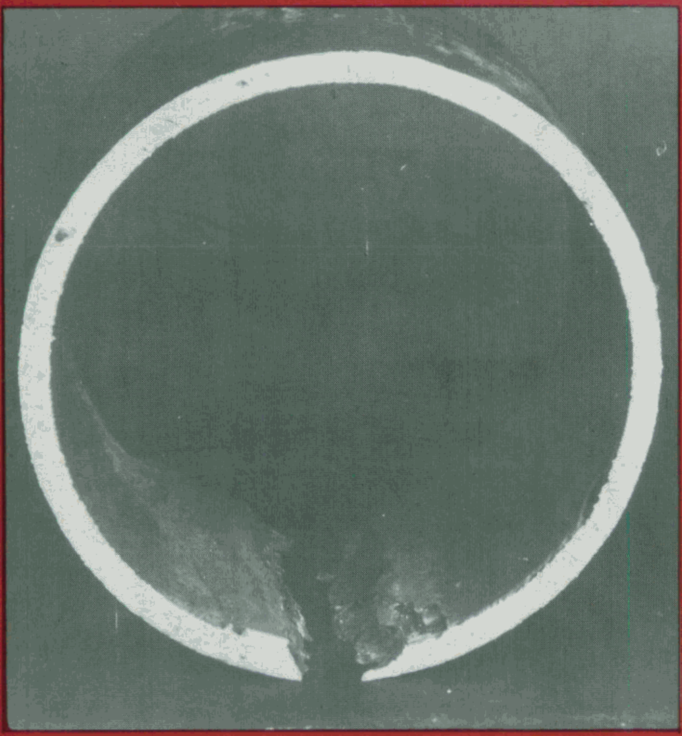
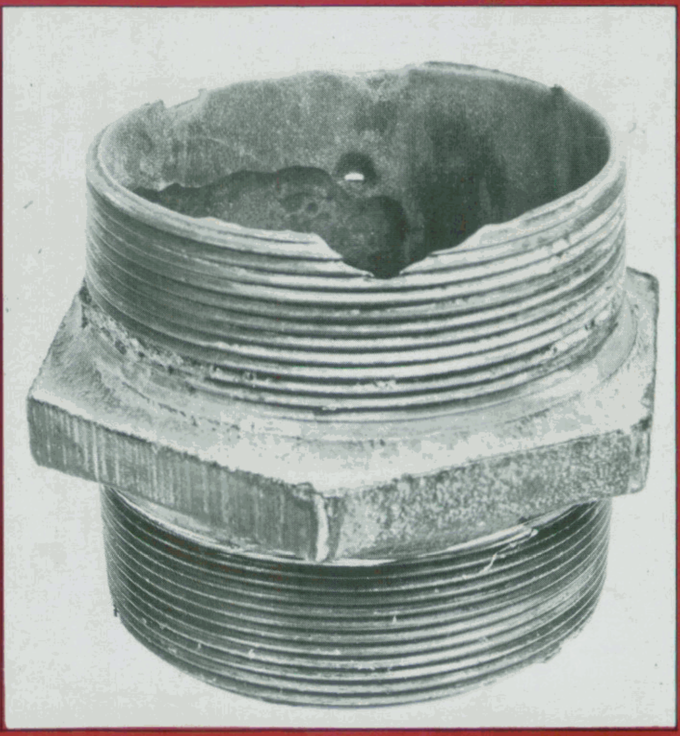
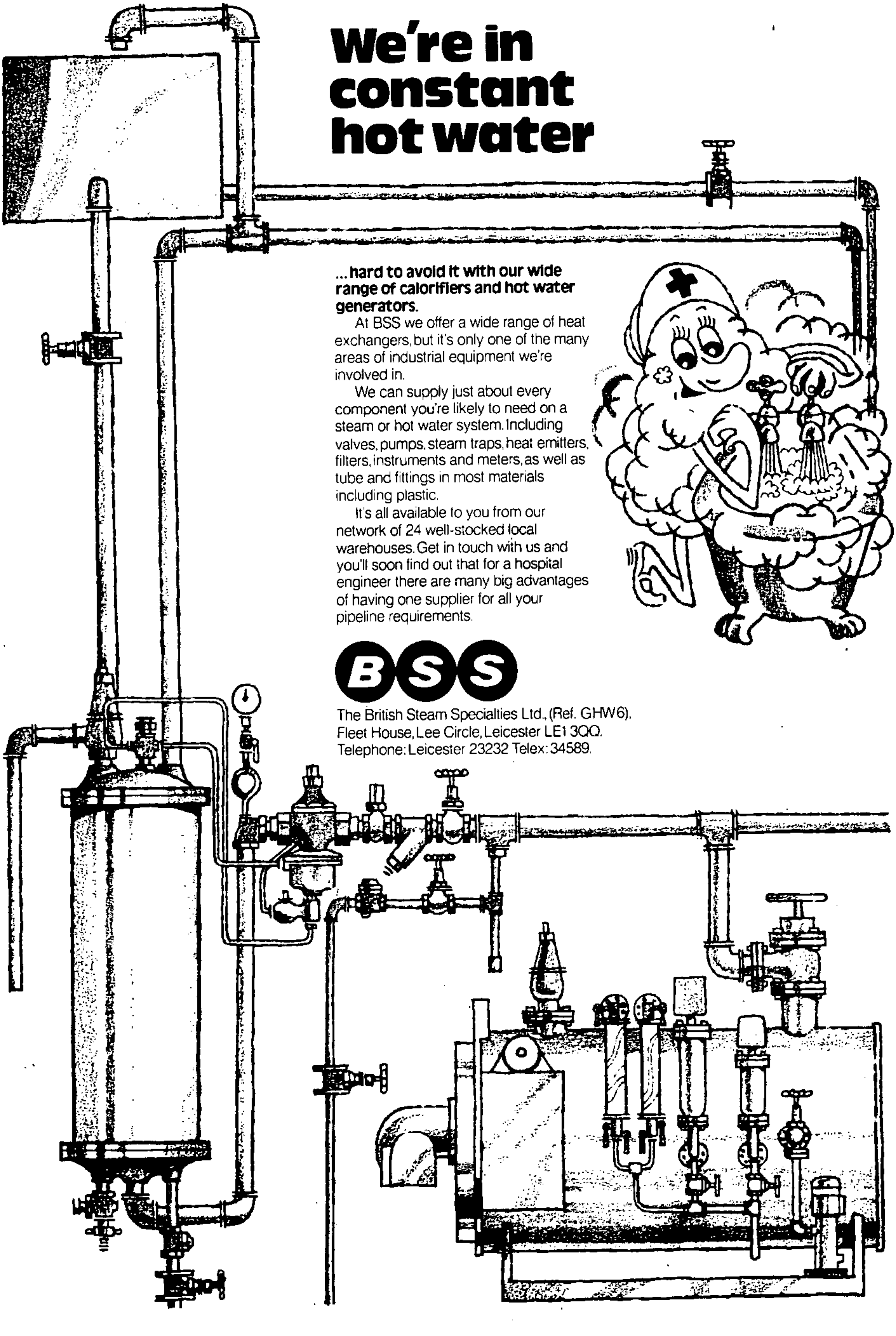






Tackling Corrosion in Condensate Lines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HOSPITAL ENGINEERING

March 1978 **Vol. 32 No. 2**

The Journal of the Institute of Hospital Engineering

International Federation Issue No. 25

Contents

Institute News

Annual General Meeting of the Institute

The 1978 Annual General Meeting of the Institute will be held at the Royal Hotel, Cardiff, on Friday, April 28, at 9.30 am.

At that meeting, resolutions will be placed before the membership dealing with the question of an application by the Institute for Affiliate membership of CEI, also certain proposed amendments to clauses in the Articles of Association relating to Corporate and Honorary Membership of the Institute.

The necessary notice of the AGM setting out the business of the meeting, including these resolutions, will be distributed to all members with the April issue of the Journal.

Northcroft Silver Medal Award to Overseas Member

Council of the Institute has approved that the Northcroft Silver Medal for 1977 shall be awarded to Mr. J. De Vries, of Holland, for his article *A New Concept of Energy Supply for Hospitals* which appeared in the March 1977 Issue of *Hospital Engineering*.

This is the first time that the Northcroft Silver Medal Award has been given to an Overseas Member since its inauguration in 1968.

Our congratulations go to the Author, and it is hoped that Mr. and Mrs. De Vries may be able to attend the Annual Conference of the Institute to be held in Cardiff at the end of April, when the opportunity will be be taken to make the presentation.

Area Works Officers' Conference at Falfield

Area Works Officers combined the AGM of their National Association with a two-day conference at the NHS Engineering Training Centre at Falfield, Gloucester, on the 5/6th January, 1978.

Apart from the tour of the excellent training facilities at Falfield, conference sessions were led by Dr. K. I. Murray, Assistant Chief Engineer, Department of Health and Social Security, on *Medical Engineering Maintenance* and Mrs. G. T. Banks, Assistant Secretary, Department of Health and Social Security on *The NHS Planning System*.

The National Association of Area Works Officers, which represents all Area Works Officers in England and Wales, and Area Maintenance Managers in Scotland, re-elected P. J. Tankard, Area Works Officer, Berkshire Area Health Authority, as Chairman and W. Nicholas, Area Works Officer, Suffolk Area Health Authority, as Secretary for the ensuing year.

Conferences and Exhibitions

Fires in Hospitals – Paris

An international study conference on fires in hospitals and nursing homes is being held in Paris from April 4 to April 6 inclusive. It is being held at the Paris International Centre (CIP) at the Place de la Porte Maillot, 75017 Paris. The reception bureau and secretariat will operate there continuously from April 4-6 between 9 am and 6 pm.

The conference will examine some case histories of recent fires in hospitals, and will discuss fire risks in the hospital environment and the way in which members of different disciplines from hospital management to engineers and fire brigades can help. They will then consider construction and organisation and fire protection equipment, before going on on the third day to considering the human factor, and how costs may be optimised. The latter session, taking place on the second half of the last day, will be under the chairmanship of Mr. J. Ponthieux, who is chairman of the International Federation of Hospital Engineers in France.

Simultaneous translation into English and other languages is available, and anyone interested in attending should contact as soon as possible Julia Stevens, Incentive Travel Manager, Air France, Georgian House, 69 Boston Manor Road, Brentford, Middx. Her telephone number is 01-568 4411. It is important to make application by March 15.

Biomedical Engineering Exhibition and Conference

An exhibition and conference on Biomedical Engineering is to be held at Imperial College, London, SW7, from April 4 to April 6. The scope of the exhibition covers a wide selection of equipment in the Biomedical Engineering field, and the conference sessions range widely, from the prospects for a portable artificial kidney, to the future of patient monitoring, and from Space Lab 1980 to the use of low temperatures in medicine. There are small fees for each session, to which admission is only by ticket, and full details are available from Holdsworth Smith Limited, 39 Victoria Street, London, SW1. 01-222 0077.

Communications '78

An exhibition on all aspects of communications is to be held at The National Exhibition Centre, Birmingham, from April 4 to 7.

Health and Safety Conference

The National Occupational Health and Safety Conference, organised by the Royal Society for the Prevention of Accidents, is being held at Harrogate in May. Simultaneously with the conference, the National Safety Exhibition, with one hundred trade exhibitors, will be held in the Royal Hall, Harrogate, from May 23-25.

British Hospital Exhibition

The British Hospitals exhibition will be held at Olympia, London, from June 5 to 8.

There will be a great number of exhibitors in every field of hospital equipment, materials, supplies and services. The exhibition is sponsored by The Institute of Health Service Administrators. The exhibition is now returning to London, its traditional venue, although the 1976 event was held in Birmingham.

East Anglian Branch

A Branch meeting was held on January 7, 1978, at Fulbourn Hospital, Cambridge.

The subject of the meeting was the Teletracer K8 communication and information system presented by Mr. R. G. Jones, Director of Cass Electronics Ltd.

Following a film showing the K8 system in operation, Mr. Jones explained the development of communication systems in hospitals throughout the world.

A lively discussion took place covering all aspects of paging systems, patient nurse-call systems and automatic plant monitoring systems.

Midlands Branch

Some members of the Midlands Branch recently joined members of the Midlands Branch of the CIBS to visit the Minworth Sewage Works. The visit also included a tour of the Coleshill Sewage Sludge Incineration Plant which was opened in February 1978.

Members were shown the working of a massive battery of 34 chamber presses, each working a six-hour cycle to de-water the sludge and produce solid sludge cakes which are mechanically transferred to three incinerators each 15 metres high.

Annual General Meeting

The Annual General Meeting is to be held on Thursday, March 9, 1978, in the Lecture Theatre at the Birmingham General Hospital, Steelhouse Lane, at 6.30 pm.

Five-Branch Meeting

It is proposed to hold the Five-Branch Meeting in Oxford on Saturday, May 20, and this year we hope to avoid Cup Final day! Further details will be circulated shortly.

London Branch

Energy Saving in Air Conditioning Systems

A meeting of the London Branch was held on Tuesday, September 27, 1977. The general subject, Mechanical Air Movement and Humidification, was under the Chairmanship of Mr. D. L. Davies, Branch Chairman.

The first speaker, Mr. Chris W. Lack, Manager, Fan Department, SF Air Treatment Limited, began by reminding the audience that fans in the United Kingdom were tested in accordance with British Standard Specification 848. The speed, capacity, pressure and horse-power of a fan of a given size is a statement of the performance of the fan for one condition of operation only, ie, corresponding with a particular point on the characteristic curve. On most types of fans the sound power level is highest at minimum efficiencies, and in the middle air volume range, the sound power rating is the quietest which normally would coincide with the maximum total efficiency. For every type of fan there are noticeable characteristics of pressure, horse-power, sound power levels and efficiencies for different air quantities which can be determined by recognised mathematical fan laws.

Fans, however, are seldom installed in air conditioning systems in 'ideal' situations, and in these circumstances could not be expected to achieve their optimum performance characteristics. It was, therefore, important to appreciate the difference between the fan performance, as measured by British Standard or other relevant test codes, to that of the unit when installed. In recent years it had been the practice to increase the fan speed if the required duty was not attained, but with energy at a premium and of prime importance to the economy of the country, it was now necessary to examine and evaluate different fan performance characteristics in system design applications more closely. Illustrating his remarks with a typical building design showing cost and energy comparisons calculated by computer and with numerous diagrams and tables, Mr. Lack demonstrated the importance of computer feasibility studies for energy conservation and cost savings.

The second speaker, Mr. Raymond M. Carr, Director, Armca Specialties Limited, spoke authoritively on the subject of steam humidification and the need for and importance of humidification. Mr. Carr explained that dry air causes irritation to the nose and throat, and with bacteria being carried in a dust-laden atmosphere, the danger of colds and virus infections was considerably increased. Several years ago it had been calculated that nearly 60% of anæsthetic explosions occuring in hospital operating theatres were attributed to static electrical discharge, which could be avoided by controlling the relative humidity at between 55-60%. A high RH would also slow the rate of drying out of exposed tissue.

A dry atmosphere will also cause works of art and paintings to deteriorate, and furniture, doors and wood panelling to crack and shrink. Books and parchments also have to be protected against a dry atmosphere. For instance, paper should contain between 6-8% water by weight. Curtains and fabric also lose their lustre, and wear excessively.

Correct moisture content and humidity control was essential. The importance of positioning the humidifier manifold in relation to the air stream and ducting to ensure proper distribution of vapour, and to avoid condensation, was emphasised by Mr. Carr. It was also important to appreciate where to position the duct temperature measuring devices, which should be at least two metres from the humidifier, otherwise the device could not measure the humidity.

The final speaker, Mr. David Arnold, Partner, Troup Bywaters and Anders, spoke as a Consulting Engineer, employing a great number of fans for many applications. Many large, modern buildings were still ignoring the energy consumption of fan systems.

Mr. Arnold stressed that practically all design codes in current use were produced before everyone became so conscious of energy problems, and should therefore be re-assessed fundamentally to ensure that future systems use minimum energy. Questions for consideration included a) how much air is necessary, and when? b) what treatment of the air is really necessary? c) what duct velocities should be used? In particular, an examination of the IHVE guide for ventilation and air change rates suggested that a reduction in the number of air changes could be achieved without being harmful to health, giving useful energy savings.

A recent paper in the Building Services Journal, had suggested that the majority of people could not determine the relative humidity level, and Mr. Arnold therefore suggested that humidification in the winter months was not really essential. The speaker argued that in these circumstances, was it not more important and practical to treat the dust source such as carpeting, lifts, etc. Mr. Arnold concluded by suggesting that ductwork velocities of approximately 7.5m/s would in general result in energy reduction.

The meeting was arranged by Mr. A. M. Gower.

Shortening the Pre-Contract Period

Mr. Gillham is Regional Director, Bovis Construction Ltd, based in Harrow, Middlesex.

The Fee System and Alternative Management Contracts

JOHN M GILLHAM MC FIOB

At the moment the Construction Industry is facing its most severe crisis since World War II, with contractors' orders for new works some 40% below the level of Spring 1973 in real terms, and if there was ever a need for teamwork between client, architect, quantity surveyor and contractor, now is the time.

Teamwork will not be achieved under the antiquated tendering system, and no doubt Sir Harold Emmerson, that distinguished Civil Servant, had this in mind when he said in his survey of the Building Industry, well over a decade ago, that "In no other Industry is the responsibility for design so far removed from the responsibility for production".

After all, in the normal traditional tender situation the competing contractors are faced with a 'fait accompli' bill of quantities, taken off from completed or well advanced designs, and they can only price what is in the bill. The client is denied the benefit of the contractor's knowledge, experience and skill in consultation with his professional advisers in weighing up the cost and time implications of alternative forms of construction, to arrive at the most viable solution, taking into account the location, site conditions, labour and material resources available, and the time required for completion. The competing tender contractors can only price what is in the 'fait accompli' bill of quantities. It is not altogether surprising that more often than not even the lowest tenderer is 'over the top' — that is above the client's budget figure — and there are then panic stations in quickly summoned meetings, ill-considered bills of reductions and a resultant hotch-potch of a building which is neither one thing nor the other.

To add insult to injury, the client eventually finds out to his cost (what everyone in the industry knows) that the co-called 'cheapest price' at time of tender is not necessarily the cheapest price at the final account stage, taking into account indifferent performance and delay in completion, with the additional inflationary and funding costs, not to mention loss of anticipated revenue on capital employed and, perhaps, incurring an additional 'dead' overhead in the abortive recruitment of new staff to service a building against repeated broken completion dates.

The tendering procedure, apart from being a lengthy, tedious process, with inflation costs ticking over like a taxi meter at 2½% per month, funding costs at some 1% per month, and lost revenue at the end of the project of many thousands of pounds per month, is certainly not conducive to harmonious relationships. The RIBA form of contract automatically sets up attitudes of 'we' and 'them' on opposing sides of the fence.

The contract manager, mindful of his responsibility to turn a keenly priced contract into a profitable one, is naturally looking for every loophole for claims and additional payment, under clause 23 covering Extension of Time, knowing which of the 12 reasons spelt out in this clause for reason of extension carry money in addition to time extension and those which do not. Thus there is a tendency for the project architect to get diverted from his proper job of design and supervision to answer a bombardment of claim letters from the contract manager. He, in turn, in concocting these letters, has been diverted from his top priority job of management, co-ordination, monitoring and control. Thus relationships tend to get soured to the detriment of the management.

As a result of Sir Harold Emmerson's comment that "in no other industry is the responsibility for design so far removed from the responsibility for production" we had the 'Banwell Report' with its message of teamwork, and the conclusion that little progress would be made until those engaged in the industry thought and acted together.

This in turn leads to more 'straight' or two-stage competitive negotiations, with the contractor appointed from an early stage to work in parallel with the design team, in the progressive development of designs using cost planning techniques to arrive at the most viable solution within the available cost limit or budget. It had the advantage of early collaboration between designer and constructor, pooling brainpower and ideas to arrive at the best solution and ensuring a thorough pre-planning of the contract, so that at least when the job started it was the implementation of a well thought out planned programme. However, even with negotiated contracts against a firm price there were still the two sides of the fence once the contract was signed. The client had no 'stake' in the contract with participation in financial savings through efficient operation which are 'lost' to the client in extra profit to the contractor. There was still the 'we' and 'them' situation.

However, with Fee Contracting, where the Management Contractor is paid a percentage Fee related to the final nett value **not** cost, an identity of interest and dual incentive are genuinely created for an efficient job since the Client gets the full saving between the actual cost on books, which are open to inspection at all times, and the final net valuation as certified by the client's own independent quantity surveyor. The management contractors obviously enhance their fee the lower the eventual cost is.

In the event of the final cost on books exceeding the final net valuation, and this excess not being substantiated to the full satisfaction of the quantity surveyor, the excess cost is disallowed. Thus there is every incentive to be efficient, and every disincentive to be inefficient. Any bright ideas thought up by the contractor during the construction of the job, producing a saving, are automatically reflected to the client's benefit in saving cost on books, whereas in a tender situation, once the contract has been signed, such bright ideas invariably result in additional profit to the contractor.

Critics of Fee Contracting say:

1. You are diminishing the risk to the contractor;

2. You have an open-ended contract.

To them I would answer "diminshing risk" yes, but surely to the equal advantage of the contractor and the client. Is it in the client's interest to have the contract for perhaps the most important venture in his business life at risk by the gambling of a fixed priced tender under which he stands to lose both ways either (a) in excess contractor's profits arising from unnecessarily high prices put in to cover high risks and unforeseen circumstances that may not materialise or (b) (more likely in the current economic climate) a jungle warfare of claims at best, or bankruptcy of the contractor at worst. This can all result only in delay, inconvenience, cost not only in getting someone else to finish the job but in lost trading revenue through failure to complete on time.

With regard to the criticism of the Fee Contract being 'open-ended' I would answer that it is no more open-ended than any tender contract lasting more than 12 months which is subject to fluctuations, and with the final account depending to a large extent on the amount of inflation incurred. At least with the Bovis Fee System the books are open to inspection at all times for the client's independent quantity surveyor to satisfy himself that all costs, including increased costs due to inflation, are properly allocated. Further, through earlier collaboration resulting from appointment from design concept stage, and close examination of 'buildability' to arrive at the most economic solution, materials can be pre-ordered to minimise inflation.

Time is, of course, money. Saving time minimises the effects of inflation and reduces funding costs, and gives an earlier return on capital employed from trading revenue. Thus on an urgent job it is possible to overlap the design and construction stages, provided care is taken to ensure a smooth continuous flow of information to provide continuity of building operations. Piling and foundations can start whilst the superstructure designs are being finalised. On a large contract work can be phased to suit the client's requirements, providing for the earliest possible progressive installation of plant.

A good Fee System should work as follows:

(i) The client's architects prepare sketch plans and an outline specification;

(ii) The Budget price is prepared by the client's quantity surveyor with the management contractor;

(iii) The client, architect, quantity surveyor and contractor meet to discuss budget and programme;

(iv) The architect prepares working drawings which he passes to the client's quantity surveyor for production of a financial control document whilst at the same time the contractor can commence building;

(v) The financial control document, which can be a bill of quantities, a cost plan or whatever is most suited to the job, is priced by the client's quantity surveyor and the contractor. It is priced nett, exclusive of overheads and profit. This is the Estimate of Prime Cost — abbreviated to EPC — or estimate of net value;

(vi) The management contractors organise and carry out the work under the direction of the architect and engineer;

(vii) During the course of the contract:

a. The quantity surveyor has continuous access to the management contractor's books and records, and ensures monthly that they are being written up correctly on the client's behalf;

b. Regular meetings of all concerned are held to discuss progress and budget — projecting, in all conscientiousness as far as is reasonably possible, the final account, so that if necessary the 'coat can be cut according to the cloth available';

(viii) At the end of the contract the quantity surveyor, allowing for any variations covering changes during the course of the work, produces a final valuation. This constitutes his independent professional opinion of what the work, as eventually carried out, should have cost net, and is called the Adjusted EPC or net valuation;

(ix) The actual final cost is then extracted from the management contractor's books, all trade and cash discounts are credited in full to the client and he is presented with the bill;

(x) The client enjoys the full saving between the cost on books and final net valuation;

(xi) Should the cost on books be in excess of the quantity surveyor's final estimate, due to factors within the control of the management contractor, then he must substantiate that excess, or it is disallowed;

(xii) The contractor is paid a fee, which covers overheads and profit. It is a percentage agreed before the work starts, and is calculated on the quantity surveyor's net final valuation of the work. It is not based on actual cost. The fee will be 'tailor made' to the job, taking into account size, scope, complexity, length of contract.

There are, of course, various forms of fee contracting, and in a good company one is open to suggestions, and is not inflexible. There is the RIBA Prime Cost Fee Contract, there is the GLC Value/Cost Contract, where the fee is also related to value and where the Client and Contractor share 50/50 savings and losses, and many reputable contractors have their own particular form of contract.

The great argument for fee contracting is that it is an equitable arrangement; under which risk is minimised for the client and the management contractor, with a genuine dual incentive and identity of interest for an efficient job through a united one team approach to contracting, everyone working for the job and all benefiting from savings.

In order to satisfy public accountability there is no reason whatsoever why there should not be limited Fee Competition. Perhaps three contractors being interviewed by the client and his professional advisers to assess the comparative management ability, in the light of current resources and commitments of the three competitors. Then balancing the management ability assessment with fee level required, one contractor can be appointed on the assessed 'best value for money' basis. This contractor will then become a member of the design/build team, implementing all the recommendations of the Banwell report.

It is, of course, essential when comparing fee offers to ensure that one is truly comparing 'apples with apples' — with such things as definition of prime cost; definition of what is covered by the management fee; what happens to cash and trade discounts — are these retained by the Contractor or credited to the client — an important point remembering that these amount to between 1¼% and 1½% overall on the average contract. Also one looks at the management organisation and expertise and experience of competing contractors in management contracting. I think it should be stressed that with a fee or management contract — the architect and quantity surveyor have their traditional role — to design and evaluate respectively; and the management contractor to build.

I can truthfully report from personal experience that with fee contracting there is a marvellous team spirit — tensions disappear, claims are minimal, resulting in a more harmonious spirit and efficient job management, which, after all, is the key to high performance.

The Fee System contract with which I have been associated is a simple 12 page document covering all the essential clauses, including Liquidated and Ascertained Damages, Variations, Practical Completion and Defects Liability, Issue of Architect's Certificates, Method of Payment, Various Insurances, Determination by Employer, with appendices covering Definition of Prime Cost and what is covered by the Management Fee. It is, however, written in much simpler basic language than the RIBA Form — the theme being one of common sense and honour between men of integrity. Whereas RIBA Clause 23 spells out 12 reasons for extension of time, all the Bovis Fee Contract states is "If in the reasonable opinion of the Architect the Works are delayed by any cause beyond the control of Bovis, the Architect shall allow a fair and reasonable extension of time".

Provision is made for payment every 14 days, and this is taken into account in fixing the fee. The object of the exercise is to improve cash flow for all concerned, reflected not only in the quoted fee, but that of subcontractors' prices. One should remember that it has been said that some £500m or more is owing to the Construction Industry at any time, at 12½% this is £62.5m per annum or some 1% of the Industry's turnover.

The client can determine the contract at any time, say through company policy changes, without any claim for loss of profit, paying the fee on the cost of the work completed to date including materials delivered.

With fee contracting the main contractor has become the client's professional management contractor, being paid a fee for the planning, management, co-ordination, monitoring and control of the project. He will probably carry out the 'bread and butter trades' such as excavation, concrete, brickwork, carpentry himself, but will sub-let the specialist trades against competitive bids.

However, on large multi-million projects an increasingly regular procedure is to appoint a management contractor on a fee related to prime cost. He will be fully responsible for the planning, management, coordination, monitoring and control of all the project, **but** will sub-let all the work against competitive bids from a carefully selected list of subcontractors. In this way public accountability is fully satisfied — every trade **being sub-let** to the keenest bidder — but the benefits of early collaboration with an experienced and competent management contractor are achieved, from a point of view of optimum economic buildability, careful selection of specialist subcontractors, the formulation of a carefully thought out construction programme and its subsequent implementation.

Work is split into convenient 'packages' — for example the foundations and the frame being sub-let to the same contractor to ensure economy of smooth continuous operation and at the same time avoid 'split responsibility' in the event of a latent defect. Flat roof covering and roof screed would be sub-let together, to avoid split responsibility.

The effectiveness of such an arrangement was demonstrated in 1971/72 on the £8m (current prices £30m) Players Horizon Factory at Nottingham, which was piled, built, planted and in full cigarette production in two years. Both the consultants, Ove Arup, and Players reckoned under normal tendering procedures the job would have taken at least another 12 months. Think of the financial implications in terms of inflation, interest charges on Funding Arrangements both on land and building, and in trading revenue. It is not surprising that the project won the 1973 Financial Times Industrial Architecture Award, being an example of client/designer/contractor joint thought and action in true Banwell Report philosophy. As a bonus to the management contractor another factory was awarded by the clients in Scotland. Management contracts have 'caught on' and following a successful performance at Liverpool General Teaching Hospital another one has been awarded to Bovis for a new Nucleus Hospital.

This is no time for 'we' and 'them' situations founded on mutual mistrust, resulting in soured relationships and inefficiency at the Client's expense, and collectively at the Nation's expense. I believe the way to shortening not only the pre-contract period but the whole design/construction period is by a true change in attitudes going forward on a truly team basis, under a fee management arrangement, with an identity of interest and dual incentive for efficient building, the client having a stake in the contract and enjoying the benefit of all savings made.

Remember the vital part the construction industry plays in the Nation's economy as a whole. It accounts for one eighth of the country's gross domestic product and more than half of the total for gross fixed capital formation. It employs directly about 9% and indirectly (with associated activities) some 20% of the male population. The fast and efficient management of building contracts is essential to the prosperity of the economy as a whole.

Alas, though, the construction industry has been treated far too long by successive Governments, irrespective of political persuasion, as the Nation's economic tap to be turned on and off at the drop of a hat.

The industry is now suffering its worst recession since World War II, and I fear that unless it can be given a major injection of new work by the Government very quickly, vital resources both of management and craftsmen will be lost for ever and that when the upturn in demand comes, and it must come one day, the construction industry may find that it no longer has the resources to implement the plans.

However, management is the key to high performance, saving time and money, and management contracting will progressively become the rule rather than the exception. The largest management contract ever placed in the UK is now proceeding for EMI's new headquarters in Tottenham Court Road, London, with Bovis.

The author is an engineer with the Engineering Division of the DHSS. The article was prepared as part of the requirements for the award of the Degree of Master of Science in Materials Selection.

He would like to thank Dr Booker of the City of London Polytechnic for assistance in the preparation of the article.

Corrosion Problems in Hospital Steam Condensate Lines and Equipment

D J EVANS BSc MSc

Introduction to the Fulbourn and Ida Darwin Hospitals

Fulbourn Hospital was founded in 1868 as the Cambridge Lunatic Asylum. Many new buildings have been erected over the years. The hospital now extends over a considerable area as outlined in *Figure 1.*

The Ida Darwin Hospital was built in 1965 as a children's psychiatric institution. The boiler house at Fulbourn was also rebuilt at this time, the then new coal fired boilers serving both hospitals with heat and domestic hot water from 1966.[1]

The boilers were converted to use natural gas with 35-second oil standby in 1972. *Figure 2,* while not strictly to scale, indicates the extent of the complex.

It should be noted that the conversion from coal to natural gas/oil caused some difficulty with the boiler tubes and tube plates.

Due to the different flame characteristics of coal and gas firing the tube plates cracked, and leaks occurred at the tube/tubeplate joint. Modification to the boiler burners overcame this problem to a large extent, but to avoid differential expansion problems due to build-up of scale, associated with water hardness, the boiler feed water is softened to 2-3 ppm in terms of $CaCo_3$ using a Permutit base exchange unit. The boiler treatment by Nalfloc Ltd consists of dosing the softened water daily with 10 lbs of A310 powder, which is sodium sulphite and acts as an oxygen 'scavenger', together with 2 lbs of A724 powder, which is sodium polyphosphate which counteracts the formation of scale and sludge, and also has an 'anti-foam' agent incorporated.

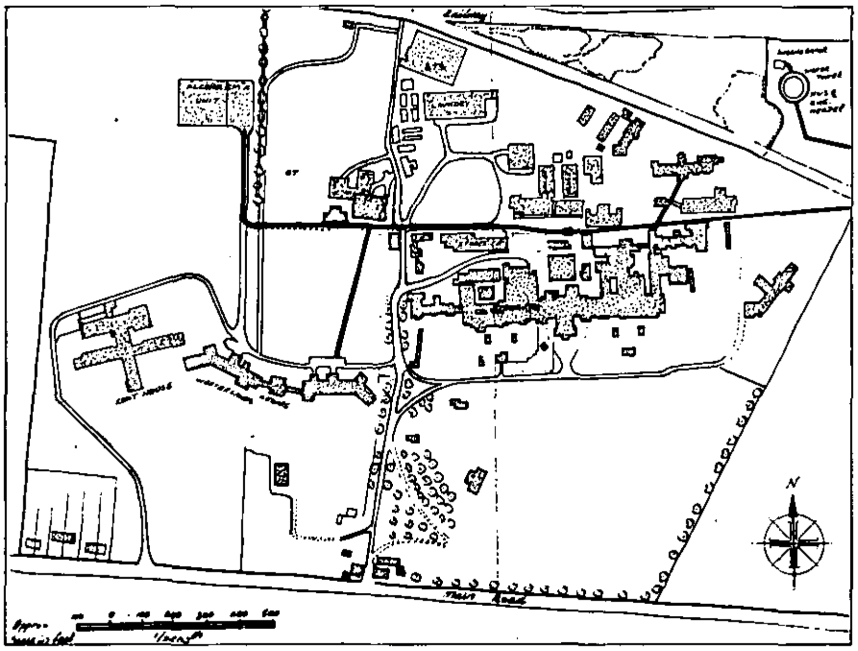
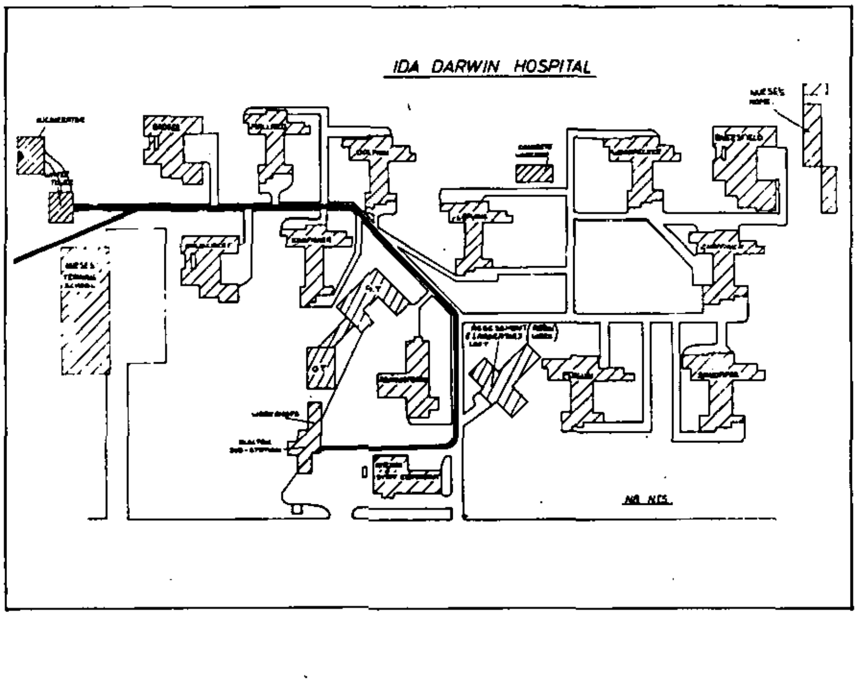


Figure 1. **Fulbourn hospital showing main steam and condensate pipe runs.**

Figure 2. **Ida Darwin hospital showing main steam and condensate pipe runs.**



It should be explained that the water in a boiler, especially under heavy load conditions, tends to 'foam' as it boils which means that more water is carried over with the steam than is desirable, as 'wet steam'.

Whilst it is true that in most steam raising plants some carry-over is unavoidable, the use of 'anti-foaming' agents is necessary to control the problem as much as possible.

A later section of this paper describes the boiler feed water treatments generally available.

Condensate Corrosion

The condensate from steam using equipment is collected by steam traps. *Figure 3* shows the situation at Fulbourn Hospital for one of a bank of three hot water service calorifiers (No 3). In this case a double bank of heater tubes is installed. *Figure 4* shows a heater tube nest removed for maintenance.

Steam is fed into the first nest. Upon exit the condensate is trapped and fed into the second tube nest, where heat from the condensate and flash steam is used, finally exhausting to the condensate receiver whence it is pumped to the hot well.

Corrosion occurs most severely in the pipe length shown on the left of *Figure 3* (a brass bleed nipple has been installed in order to sample test the condensate pH at this point). The corrosion encountered is as shown in *Figure 5*, the acidity of the condensate being mainly responsible. The reasons for this are discussed fully below.

Figure 6 shows a similar hot water storage type calorifier at the Ida Darwin Hospital. The condensate return pipe has recently been replaced here in copper under a minor capital works programme, reduced in diameter 2in. to 1½in in an effort to keep the condensate pipes full, since there had been much evidence of grooving taking place at the water line/air interface within larger diameter pipes. In fact the original collector or header pipes installed to take condensate from each bank of calorifiers to the receivers in both hospitals have also been reduced in diameter in an effort to overcome this problem.

Figure 7 shows the condensate return pipe from No 3 heating calorifier at Fulbourn Hospital. Again the corrosion is most severe in the short downward sloping part of the pipe run. While this length of pipe is ahead of the steam trap, condensate would be forming and running along the

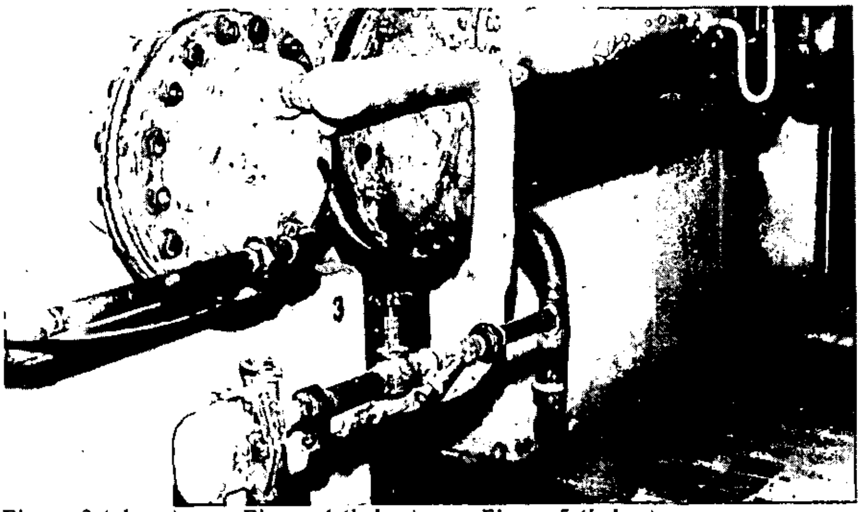
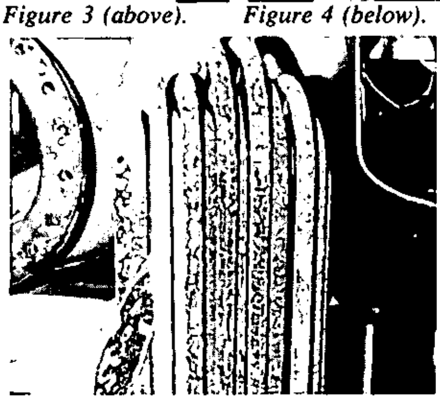


Figure 3 (above). *Figure 4 (below).* *Figure 5 (below).*



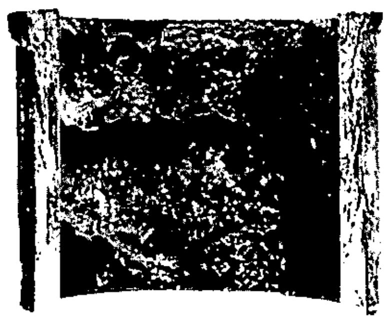
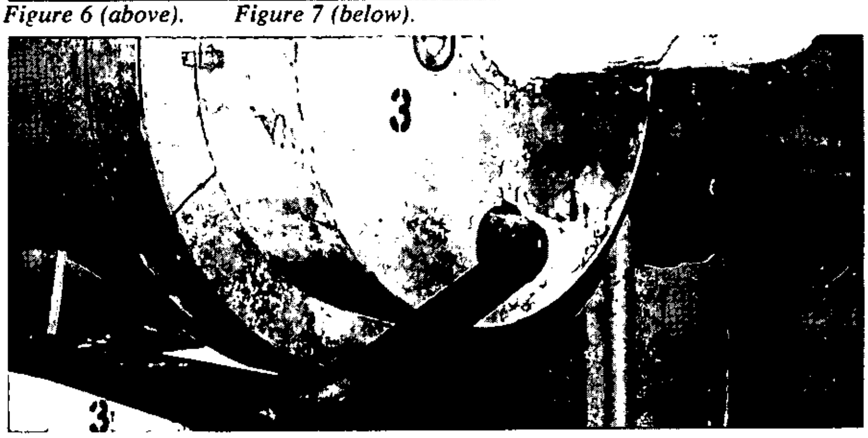


Figure 6 (above). *Figure 7 (below).*



bottom part of this pipe, due to the heat given up to the calorifier, the temperature still being high at approximately 300°F (150°C).

The foregoing are typical of the problems encountered with condensate pipes close to the calorifiers. Severe corrosion also takes place at both Fulbourn and Ida Darwin Hospitals in the pipes connecting the main 'header' pipes to the receiver. *Figure 8* shows the general situation at the Ida Darwin Hospital, the 3in diameter vertical pipe lasting approximately six months. It should be noted that all the mild steel piping shown was originally in copper, the life of which was, of course, considerably longer than that experienced using the mild steel.

Replacement in mild steel was tried as it is cheaper and easier generally to fabricate than the copper pipe. *Figure 9* shows the groove or cut made by the condensate running down the 3in vertical pipe.

Figure 9.

The bottom of the manifold pipe, *Figure 8*, also fails due to corrosion but a design fault is probably responsible here as the water tends to lie in the bottom of the pipe.

The hospital staff have redesigned this item in an attempt to overcome this, the connections are all 'swept' into the main pipe and each side of the tee is angled to drain into the main receiver connecting pipe.

Corrosion Problems associated with Steam Traps

Apart from condensate return pipe failure along the main return lines from outlying parts of the hospital the steam traps and pumps also suffer from severe corrosion, *Figure 10* shows the floats taken from Spirax Ogden Automatic pumps.

Figure 11[2] shows working parts of the apparatus while *Figures 12* and *13*

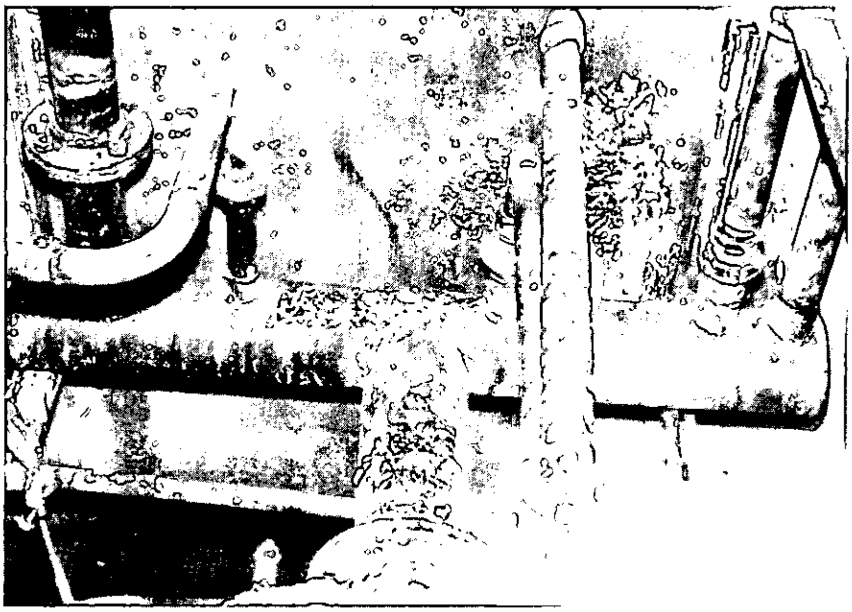
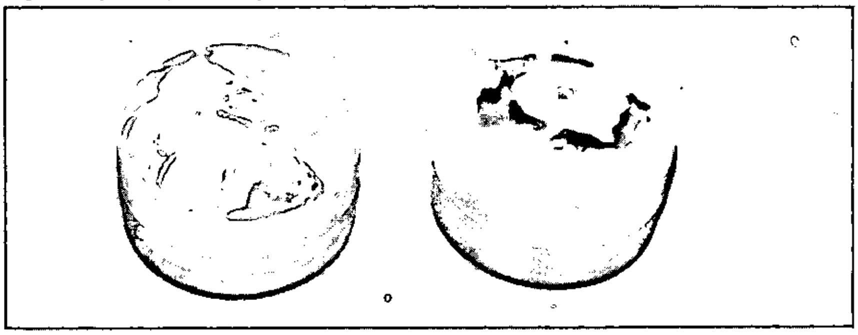


Figure 8 (above). *Figure 10 (below).*



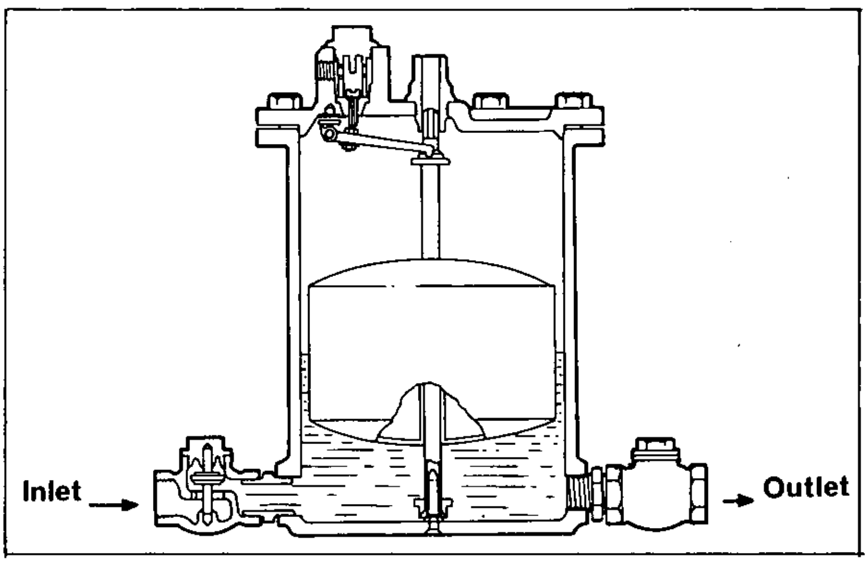


Figure 11. **Ogden automatic pump.**

Operation: Liquid from the receiver flows by gravity into the pump through the inlet check valve, raising the float to engage the collar of the exhaust valve spindle and partly close the exhaust valve, at the same time cracking open the inlet valve. Pressure of incoming steam, compressed air or gas snaps the exhaust valve on to its seat and opens inlet valve fully. (Where there is insufficient back-pressure to give the snap action, it is created artificially by a spring-loaded outlet check valve). Pressure of the *operating medium discharges the liquid through the outlet check valve until the weight of the float on the bottom of the spindle pulls the exhaust valve open to vent the pump body. Simultaneously, the inlet valve closes. Liquid again enters the pump and the cycle is repeated. The operating medium is reduced in pressure through the inlet valve, which admits only sufficient to lift the liquid the required height. Consumption of steam or compressed air is negligible.*

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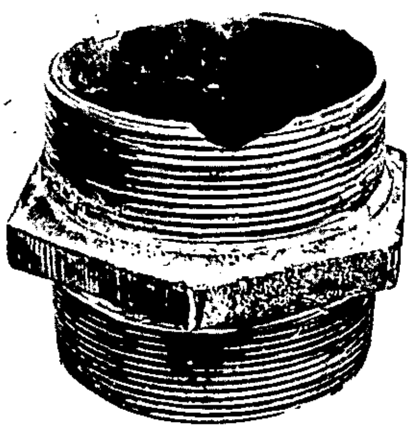
show the working situation of the pumps being discussed. Note the leak coming from the nipple on *Figure 14*. This part is shown in *Figure 15* after removal. It had been in service for only two weeks.

Figure 15.



The cover of a Spirax FT 600 Steam trap also suffered severe corrosion after only six months' service in the Fulbourn Alcoholism Unit Plant room.

The material of this cover is malleable iron, which is not generally as corrosion resistant as cast iron. Malleable iron is, however, used by the manufacturers as experience has shown that a good steam tight joint is made with this material without the risk of breakage, which could easily occur with cast iron.

The buckets from a Spirax Ogden Open Bucket Steam trap, see *Figure 16*,[3] also suffer corrosion mainly at the welded vertical seam, and to a lesser extent around the welded-in bottom. It should be noted that the welding is carried out on one side only, forming a crevice giving rise to a crevice corrosion situation.

This point was taken up with the manufacturers, and it was indicated that manufacturing methods and costs dictated the method adopted.

Since the initial discussions, however, production of this type of steam trap has now been terminated.

A Spirax Drayton inverted bucket steam trap as *Figure 17*[4] is now considered to be more suitable for the duties.

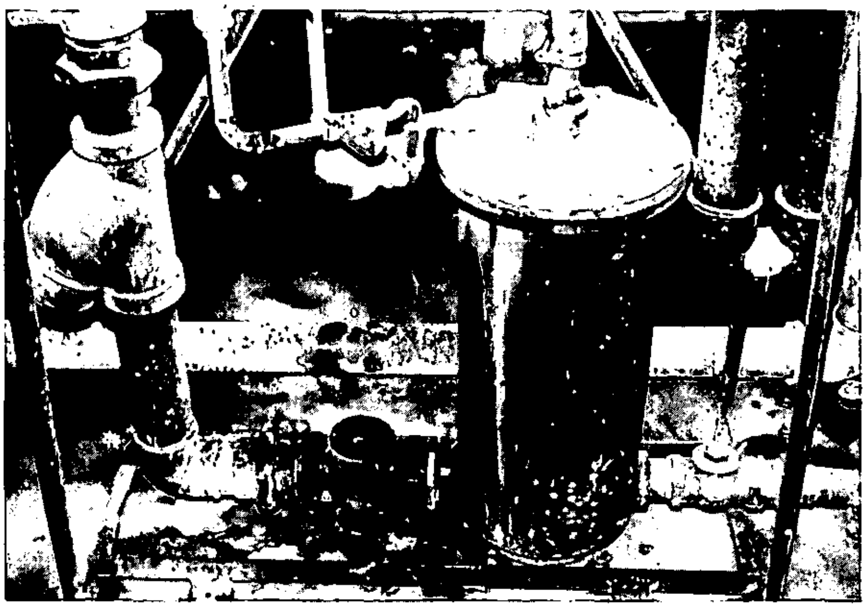


Figure 12.

Figure 13.

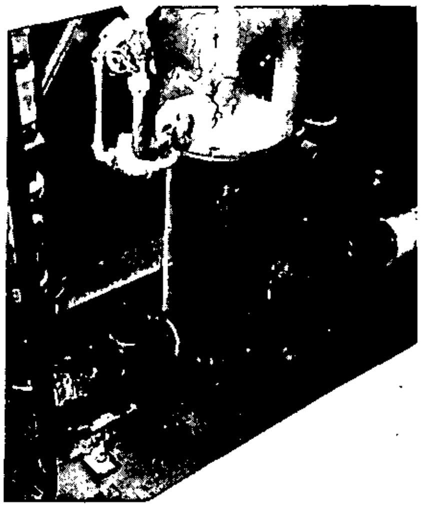


Figure 14.

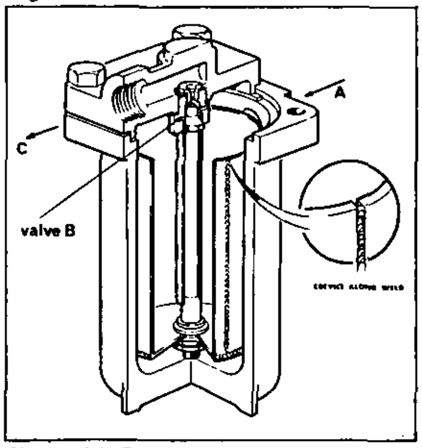
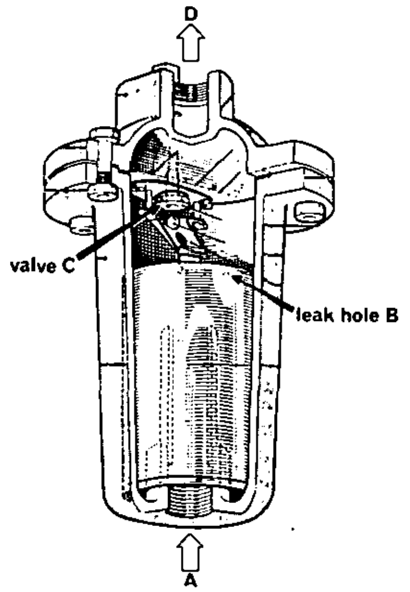


Figure 16. **Open-top bucket steam trap.**

Operation: Steam and condensate enters at A, the bucket floats in the rising condensate until the valve B is closed. The condensate level continues to rise and fills the bucket, which losing buoyancy allows the valve to open. The steam pressure blows the condensate out of the bucket and out through the discharge pipe C.

Figure 17. **Inverted bucket steam trap.**

Operation: Steam and condensate enters at A, any air trapped in the bucket escapes through the leak hole B. Condensate continues to accumulate in the trap body and bucket. Provided the condensate enters fairly fast, the leak hole is inadequate to even out the pressure inside and outside the bucket, so that the water level rises faster outside than inside, giving the bucket buoyancy. When sufficient



water has risen inside the bucket however, the buoyancy is lost and the valve C is opened. Steam pressure then blows the water out from both inside and around the bucket, through outlet D. This type of trap is an improvement on the open top bucket trap in that condensate is not left in the bucket and air is always expelled, (the open top bucket trap can become air locked). A small amount of steam is lost through the leak hole on discharge but the quantity is negligible.

Boiler Feed Water Treatment

The Purpose of Water Treatment

The reasons for boiler feed water treatment are twofold.

a. To prevent corrosion within the boilers, boiler water feed lines, steam and condense main pipe lines;

b. To prevent the build-up of scale on the boiler heating surfaces. If this is allowed to occur it results in:

(i) Reduced boiler output;

(ii) Reduced heat transfer;

(iii) Reduction of boiler life through overheating metal;

(iv) Increased maintenance costs;

(v) Failure of swaged tube ends, due to the differential expansion which takes place between the tube plate and tube.

In order to assess with any degree of accuracy the treatment required for any particular raw water supply, a full analysis of the water must be obtained. This may come from the Water Authority or, as has been done in the cases considered in this report, from the boiler water treatment firms, who usually offer this analysis as part of their service.

Water Supplies

The original source of all natural water supplies is rain, impurities being collected in the passage through the air and the various strata of the earth as the water passes through them. Whilst the waters vary in composition, according to their previous history, the impurities collected are comparatively few:

(i) Mineral salts, consisting of bicarbonates, carbonates, chlorides, sulphates and nitrates of calcium, magnesium and sodium. Small amounts of Silica may be present and dependent upon location the water may contain appreciable quantities of iron and aluminium salts;

(ii) Dissolved gases, oxygen, carbon dioxide and possibly acid vapours;

(iii) Suspended matter, mineral or organic.

The amounts of these impurities will depend upon the origin of the water supply. As the suitability of a water for boiler feed depends on the effect of the impurities, it will be useful here to briefly review the various natural water supplies.

Rain Water

Rain water will, of course, take up impurities as it falls through the atmosphere, mainly dissolved gases and dust. It is soft, but does contain substantial amounts of dissolved oxygen and carbon dioxide, which are corrosive gases. A more dangerous source of corrosion in rain water is, however, the acidity it may acquire in passing through polluted atmospheres. Many modern industrial processes result in the production of acid gases, which are released to the atmosphere, and concentration will depend upon types of industry in any particular locality — eg coal burning results in the sulphuric content of the rain being high.

Other industrial areas may give rise to iron oxide, silica sulphate and carbonate lime, ammonium chloride, magnesium sulphate, sodium chloride and other organic matter being found in an analysis of the rain water.

Nitric acid produced by the electrical oxidation of nitrogen in the air during a thunderstorm may also be present. Rain in coastal areas may contain appreciable amounts of sodium chloride.

Even if so-called pure rain water is used as the source of water for boiler feed, it must be carefully monitored so that free acidity or dissolved gases do not pass to the boiler. Treatment will, in almost all cases, be necessary.

Surface Water

Rain water either passes through the earth, or remains on or near the surface forming lakes, streams or rivers. In either case the acids and acid gases it contains assist the solution of further impurities.

Surface waters are generally saturated with dissolved gases due to their exposure to the atmosphere. They also contain appreciable amounts of suspended matter and in moorland districts the water may be contaminated with organic or peaty matter which is liable to decompose giving off humic acid. The water, while being very little harder than rain water, is still corrosive and requires treatment.

River Water

Rivers are mainly fed by surface water, so that the amount of contamination depends upon the nature of the collecting grounds. The water will generally be less pure than rain water, the actual composition being subject to the river flow and the time of the year.

Suspended matter will vary at any given point due to rate of flow. It will be high at the source or where the rate of flow is rapid and low when the river widens or the rate of flow diminishes due to the deposition of suspended matter.

Tributaries, however, repeatedly add to the suspended matter, so the water is never very free from fine particulate suspended material which is difficult to remove.

Dissolved oxygen and carbon dioxide will also be present as could other chemicals from factories discharging trade waste and effluent and treated or untreated sewage.

Spring Water

As has been mentioned, rain water contains appreciable amounts of CO_2, making the water acidic and increasing its dissolving power, so that as the rain water passes through the ground it takes up calcium and magnesium carbonates in the form of bicarbonates. Under the action of heat these substances decompose to give back the original gases and carbonates.

Spring water does not contain suspended matter due to the filtration effect of its passage through the porous strata and, as outlined above, it is not acid — springs being fed from rain water sources.

Dissolved oxygen will also be low as the water is not continually exposed to the atmosphere.

Spring water, therefore, has to be treated to remove any dissolved gases it may contain, and to counteract the effect of the scale forming and corrosive dissolved salts.

Well Water

There are two classes of well—shallow and deep. Generally only the latter would be used for industry or public undertakings. Deep wells may be compared to springs in that the water percolates through the ground and, in the case of a spring, reaches a fault in an impervious layer or stratum and thus makes its own outlet, whereas in the case of wells, the water accumulates at an impervious stratum and may be tapped. The water is, therefore, similar to that of springs, the dissolved solids consisting of carbonates and sulphates. Deep wells may be strongly alkaline due to a sodium carbonate content, being the result of zeolite action, the water passing through natural beds of zeolite/aluminosilcate and having its calcium and magnesium carbonates changed to sodium carbonate by the base exchange action of the mineral. This is fully described in a later chapter.

Canal Water

These waters would not normally be considered for boiler feed water due to high amounts of suspended matter. They may also be acid, due to water pumped from mines and other industrial effluents. High amounts of dissolved sulphates and iron may also be present in suspension.

Pit Water

Again not recommended for boiler feed water due to generally high acidity and substantial amounts of sulphates. It can happen that two different waters are obtained from one pit, one seam giving a hard acidic water and the other an alkaline water. These may be combined to give a suitable boiler feed, but is unusual.

Effects of Drought

This topic is thought to be appropriate here in view of what happened in 1976. As has been indicated, spring and well waters are affected by rainfall. The character of a water may be completely changed if the bulk is normally supplied by rain which dilutes a more objectionable minor part of the well water obtained from another source. If, during a drought the dilution is much reduced or negligible, then the undesirable nature of the second source will be made apparent. Contamination by effluent has already been mentioned in connection with river and canal supplies. These are more serious in a drought, being a larger proportion of the water as a whole. Fertilisers on agricultural land which drain to a river are also a cause of acidity increase. Drought conditions, therefore, can result in wide fluctuation of water content necessitating constant vigilance on the part of plant operators.

Acid and Alkaline Waters

In general, if water is from an upland source which is peaty, then it will be acidic and give rise to corrosion in the boiler if untreated. If water is from a well or borehole in limestone and chalk areas it is alkaline and the dissolved solids will give rise to scale and sludge deposits inside the boiler.

Measurement of Acidity/Alkalinity

This measurement is on the pH scale. This scale has been developed as a convenient method of expressing the hydrogen ion concentration. The importance of which was first indicated by Wolman and Hannan, with regard to boiler feed water in 1921. In those early days it was only possible to find if a supply of water was acid or alkaline by using Litmus paper, red for acid, blue for alkaline. Nowadays the hydrogen ion concentration may be accurately measured instrumentally.

According to the theory of electrolytic dissociation all aqueous environments contain free hydrogen ions (H^+) and hydroxyl ions (OH^-).

When the number of hydrogen ions exactly equal the number of hydroxyl ions the solution is said to be neutral, excess of hydrogen ions indicates acidity while excess of hydroxyl ions indicates alkalinity.

It is sufficient to say here that there is 1 gram of hydrogen ions in 10 million litres of pure water and, of course, a similar quantity of hydroxyl ions in pure distilled water which is neutral.

$$\text{Ie,} \quad C_H \times C_{OH} = 10^{-7} \times 10^{-7} = 10^{-14}$$

so that if one concentration is known then the other is readily ascertained. Therefore, only the hydrogen ion concentration is quoted. The Law of Mass Action states that the product of the concentrations is a constant at any given temperature and for water this defines the ionisation product as $Kw = 10^{-14}$.

The pH is the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration in grams per litre.

$$\text{Ie,} \quad pH = \log \frac{1}{[H^+]}$$

$[H^+]$ being the concentration of hydrogen ions in grams per litre.

Therefore, pure water with a hydrogen ion concentration of 10^{-7} has a pH value of 7.0.

Above this figure the water is alkaline and below, it is acidic.

Hardness of Water[6, 7]

Hardness was expressed as temporary or permanent.

Temporary Hardness

refers to that part of the hardness due to the presence of carbonates and bicarbonates of calcium and magnesium. These may be precipitated by boiling, hence the term temporary, but this is now replaced by the term *carbonate hardness* which is generally the same as the total alkalinity.

Permanent Hardness

is due to the presence of the sulphates, chlorides and nitrates of calcium and magnesium. This is now termed *non-carbonate hardness* and will remain after boiling.

Total Hardness

is the sum of the carbonate and non-carbonate hardness. This is mainly due to the calcium and magnesium salts which deposit on the metal surface as calcium carbonate, magnesium hydroxide and scale. As has been mentioned previously, these are poor conductors of heat, and the heat transfer to the boiler water is reduced while the temperature of the metal increases. Failure may therefore occur due to a reduction in mechanical strength or overheating under layers of corrosion deposit.

The Langelier Index and Scale Formation

This index uses known constants and the amounts of the principle carbonates present in a water in order to determine if deposition of calcium carbonate will occur.

The solubilities of the principle carbonates in ppm in terms of $CaCO_3$ are:

Calcium carbonate $CaCO_3$	13
Magnesium carbonate $MgCO_3$	75
Sodium carbonate Na^2CO_3	289,000

The total amount of carbonate present in water is controlled by the solubility of $CaCO_3$ solubility product Ks

$$Ca^{++} + CO_3^{--} \rightleftharpoons Ca\,CO_3 \text{ (solid)}$$

$$[Ca^{++}]\,[CO_3] = Ks.$$

And the dissociation constant of water $Kw = [H^+]\,[OH^-]$.

From bicarbonate equilibria equations and those above a solution saturated with a $CaCO_3$ has a pH value, pH_s.

$$pH_s = pK_2 - pK_s + pCa^{++} + p\,\text{Alkalinity} + [H^+] - \frac{Kw}{[H^+]} - p\,\frac{1 + 2K_2}{[H^+]}$$

p representing the negative logarithm of the appropriate quantity,

$$K_2 = \frac{[H^+]\,[CO_3^{--}]}{[HCO_3^-]}$$

the second dissociation constant. K_w and K_2 are known over a wide range of temperature so that if the calcium hardness, total alkalinity, the pH and temperature are known then the saturation pH, pH_s may be calculated.

Actual water $pH - pH_s$ is the Langelier index, if the result is positive $CaCO_3$ will deposit, ie scale forms, if negative then the $CaCO_3$ is still soluble.

If the data for calculation is not available then a marble or chalk test may be used instead, chalk or marble being added to equilibrium and the change in pH and alkalinity indicates whether $CaCO_3$ has been deposited or left in solution.

Scale formation is a very important factor in the economic operation of boiler plants as has been indicated due to the heat transfer considerations and the differential expansion of the tubes and tube plates, gives rise to maintenance expenditure when leaks inevitably occur.

Another economic loss can be experienced by the excessive 'blow down' of solids from the boiler. In this connection the water contaminants may be regarded as either scale or sludge formers. Calcium carbonate is a sludge former as are calcium phosphate and magnesium hydroxide, calcium sulphate being a scale former. It should be noted, however, that calcium carbonate and magnesium hydroxide can bake onto boiler tubes. Silicates form hard adherent scale which is difficult to remove. Whether a scale or a sludge is deposited depends upon the presence of nuclei on which the sludge can form.

The economics of boiler blow down will not be considered in this report but it is an important aspect of efficient steam boiler operation. It will be sufficient to say here, however, that at Fulbourn Hospital the system in operation at present is manual blow down, as much as four to five times per eight-hour shift depending on the total dissolved solids (TDS) — shown on a calibrated hydrometer. This is to be replaced by a continuous blow down system in the near future.

At present the blow down is from the bottom of the boilers. This is probably the best position for ridding the bottom plates of sludge which could harden into a scale, but the suspended salts which tend to be nearer the water surface are not blown out. Continuous blow down systems take the water from approximately two inches below the surface so that if such a system is used measures should be taken to avoid sludge formation.

Methods of Boiler Feed Water Softening and Conditioning

These are either external or internal.

External

External means treatment of the fed water prior to being fed into the boiler. Many treatments are available.

Base Exchange Process

The principle is the exchange of scale forming calcium and magnesium salts for soluble salts by passing the raw water through originally natural or synthetic zeolites, basically sodium aluminium silicate. High capacity polystyrene resins are now used, however, being more efficient than the older zeolites. As the calcium and magnesium ions are replaced or exchanged by the sodium ions from the resin, the exchange capacity of the resin will become exhausted after a certain time. The resin is then regenerated by passing a solution of NaCl (salt) through it.

The chemical reactions are as shown in *Equations 1* and *2*.

The sodium sulphate and other products from *Equation 2* are virtually harmless as constituents of boiler feed water but the sodium bicarbonate from *Equation 1* is objectionable from many points of view. It is readily decomposed by heat, releasing CO_2 to the steam and leaving sodium carbonate and/or caustic soda in the boiler water, the reactions being as shown in *Equations 3* and *4* opposite.

The presence of CO_2 in the steam leads to serious corrosion at any points where condensation occurs, while excessive alkalinity in the boiler due to caustic soda may set up leakage at joints, acting on non-ferrous fittings, foaming or caustic embrittlement.

When the base exchange resin is exhausted of exchangeable ions, it is regenerated with sodium chloride, a reverse exchange action (see *Equation 5*).

It will be noted for use with water analysis that the high temperature conditions within a boiler cause complete decomposition of the bicarbonate alkalinity and approximately 80% breakdown of the carbonate alkalinity, equations (3) and (4) may be rewritten as shown opposite.

For each 100 ppm of boiler feedwater 79 ppm of CO_2 is given off with the steam and for each 100ppm of carbonate 35 ppm of CO_2 is evolved.[12]

Lime Soda Softening

This process softens the water by controlled additions of lime and soda ash. There are two types of plant, cold process or hot process. Both depend upon certain essential factors:

(i) Correct proportioning of specific chemical reagents and raw water;

(ii) Propagating the chemical reactions by which precipitation of the hardness is affected. This requires a suitable combination of coagulation, sedimentation, heat or sludge contact;

(iii) Filtration of the chemically softened water to remove any traces of turbidity or suspended matter. The process consists of conversion of Ca and Mg salts present in the raw water into insoluble solids which are precipitated. The chemical reactions for the process are given below.

Lime Treatment

(a) Removal of temporary hardness due to calcium bicarbonate.

Equation 6

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$$

(b) Removal of temporary hardness due to magnesium bicarbonate.

Equation 7

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \longrightarrow Mg(OH) + 2CaCO_3 + 2H_2O$$

(c) Removal of free carbon dioxide from the raw water.

Equation 1

$$\left\{\begin{matrix} Ca\,(HCO_3)_2 \\ Mg \end{matrix}\right\} + 2\,NaR \rightarrow 2Na\,HCO_3 + \begin{matrix} Ca\,R_2 \\ Mg \end{matrix}$$

Equation 2

$$\left\{\begin{matrix} Ca & SO_4 \\ Mg & (NO_3)_2 \\ & Cl_2 \end{matrix}\right\} + 2\,NaR \rightarrow \begin{matrix} Na_2\,SO_4 + Ca\,R_2 \\ NaNO_3 \quad Mg \\ NaCl \end{matrix}$$

NaR represents the complex sodium exchange radical.

Equation 3

$$2NaHCO_3 \xrightarrow{Heat} Na_2CO_3 + CO_2 + H_2O$$

Equation 4

$$Na_2CO_3 + H_2O \longrightarrow 2NaOH + CO_2$$

Equation 5

$$\begin{matrix} CaR \\ Mg \end{matrix} + NaCl \longrightarrow Na\,R + \begin{matrix} CaCl_2 \\ Mg \end{matrix}$$

Equations 3 and *4* as rewritten:

$$\frac{2NaHCO_3}{100 \text{ as } CaCO_3} \xrightarrow{heat} \frac{Na_2CO_3}{100 \text{ as } CaCO_3} + H_2O + \frac{CO_2}{44}$$

$$\frac{NaCO_3}{100 \text{ as } CaCO_3} + H_2O \longrightarrow 2NaOH + \frac{CO_2}{44}$$

CO_2 from bicarbonates = 44 + (0.80 × 44) = 79
CO_2 from carbonates = 44 × 0.80 = 35

Figure 18. **Diagram of Base Exchange process.**

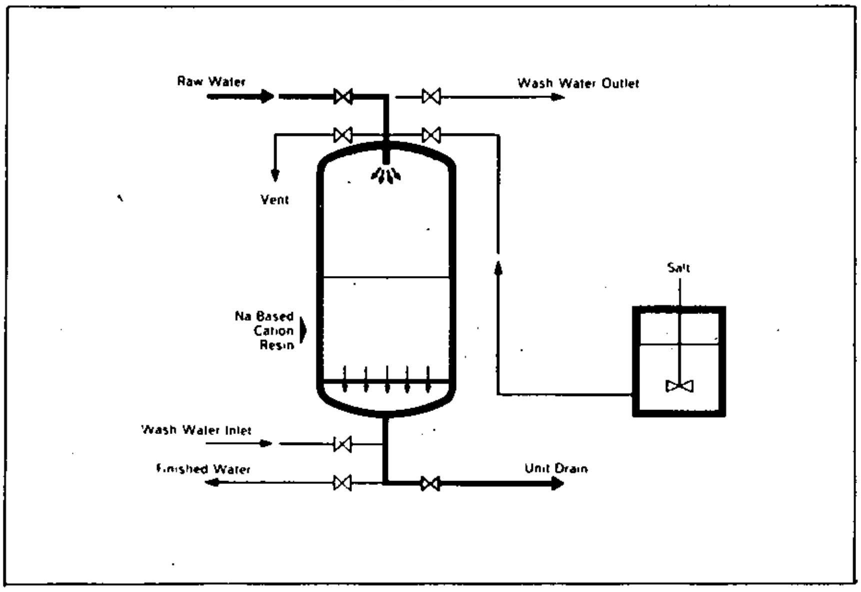
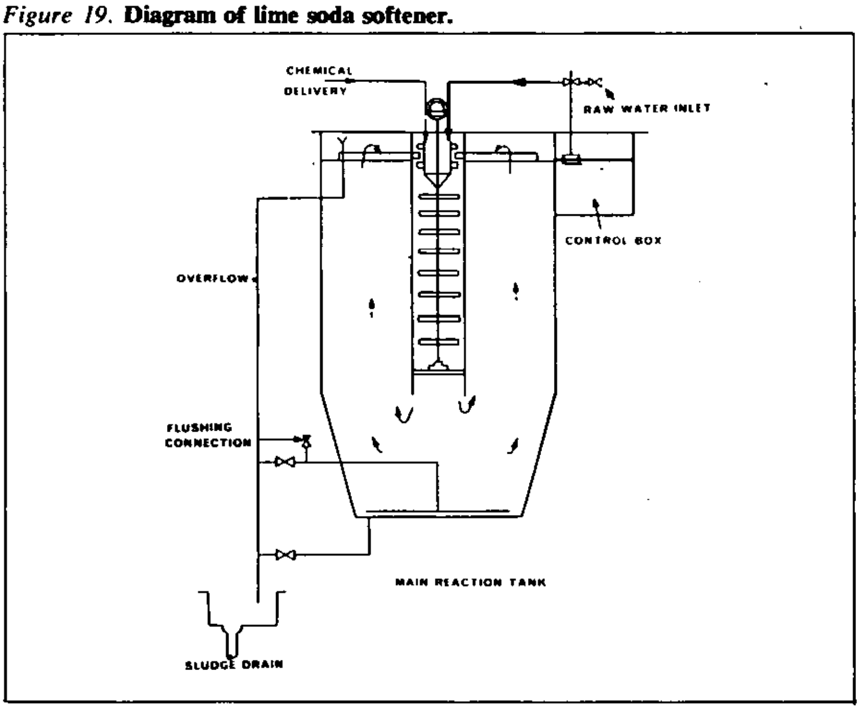


Figure 19. **Diagram of lime soda softener.**



Equation 8

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$

(d) Removal of permanent hardness due to magnesium salts.

Equation 9

$$\begin{matrix} MgSO_4 \\ MgCl_2 \\ Mg(NO_3)_2 \end{matrix} + Ca(OH)_2 \rightarrow \begin{matrix} Ca(NO_3)_2 \\ CaCl_2 \\ CaSO_4 \end{matrix} + Mg(OH)_2$$

Soda Ash Treatment

Removal of permanent hardness due to calcium salts.

Equation 10

$$\begin{matrix} CaSO_4 \\ CaCl_2 \\ Ca(NO_3)_2 \end{matrix} + Na_2\,CO_3 \rightarrow \begin{matrix} Na_2SO_4 \\ 2\,NaCl \\ 2\,NaNO_3 \end{matrix} + CaCO_3$$

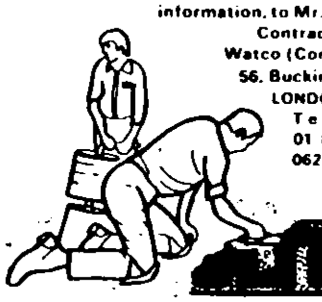
The sodium salts formed as a by-product are non-scale forming.

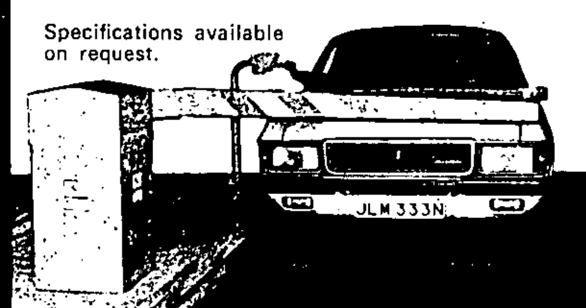
This type of softening process is not as popular as base exchange, as the plant is large and expensive and can be messy to operate, and for good results continual monitoring of the raw water quality is essential.

If, however, all the disadvantages can be accepted the resultant water, while being still slightly hard, has lower total dissolved solids, so blow down is less than that required using feed water softened by the base exchange process.

De-mineralisation and De-ionisation

When dealing above with base exchange methods of water softening, it was pointed out that the bicarbonates of calcium and magnesium, the cause of temporary or 'alkaline' hardness, were changed to sodium bicarbonates, which were readily decomposed by the heat of the boiler, releasing CO_2 to the steam and leav-

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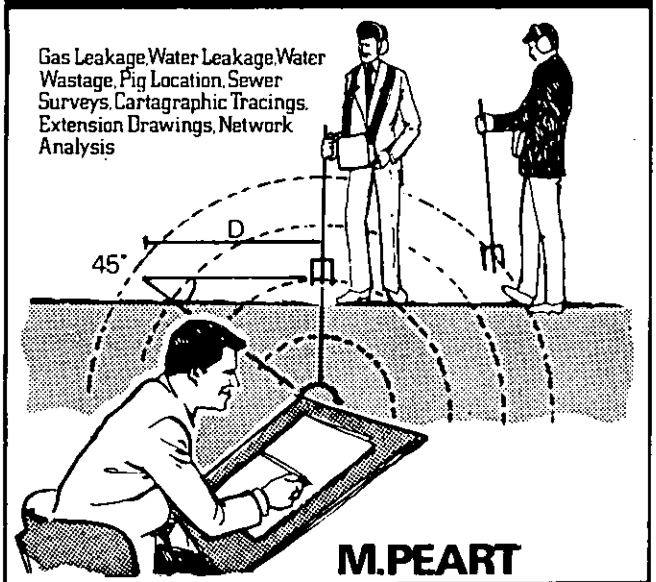
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ing sodium carbonate and/or caustic soda (NaOH) in the boiler water. This results in corrosive action by the condensate, and attack on joints, foaming or caustic embrittlement by the caustic soda in the boiler.

In the base exchange method of treatment the two cations Na^+ take the place of the cation Ca^{++} in the calcium bicarbonate, and so produce sodium bicarbonate which does not cause hardness.

Further research showed that other exchangers could be found, either cationic or anionic in type. Thus, if it is desired to exchange hydrogen ions for other cations, a suitable exchanger is first contacted with a mineral acid solution (eg HCl or H_2SO_4) from which hydrogen ions are extracted by the exchanger. The resin in the exchanger will exchange its hydrogen ions for other cations in water such as calcium, magnesium etc.

Anion exchangers behave in a similar way and transfer anions only. Thus, an anion exchanger regenerated with caustic soda (Na OH) will retain the hydroxyl ions (OH^-) and in water will readily exchange these anions for the other anions such as carbonate, chloride, sulphate etc.

Various combinations of cation exchange and base exchange can be used to produce boiler feed waters which are soft, non-corrosive and substantially reduced in dissolved solids.

De-alkalisation softening

This arrangement of plant is very suitable for the treatment of waters having a high alkaline hardness, as these dissolved solids are eliminated. Cation exchange only, and three process steps connected in series are used:

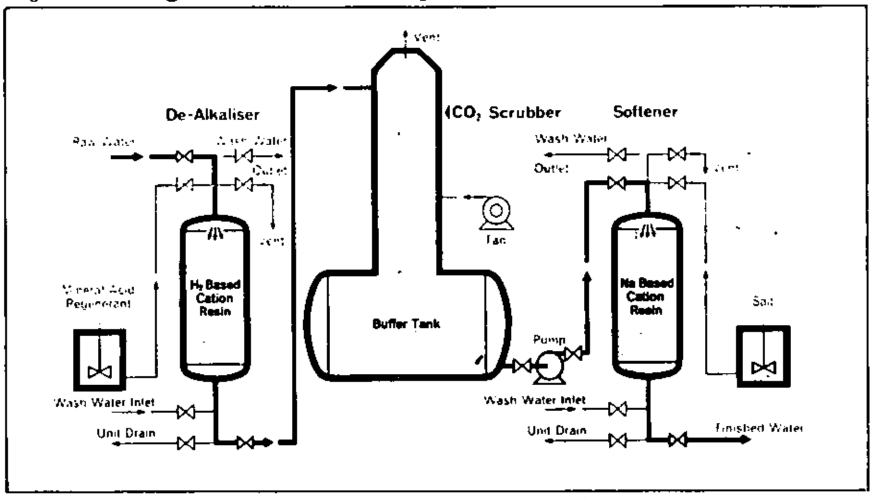
(A) A hydrogen ion exchanger in which the bicarbonates making temporary hardness are converted into carbonic acid. A weakly acidic ion exchange resin is used, which is sensitive to the salts of weak acids and permits sulphates and chlorides (permanent hardness) as strong acid salts to pass through unchanged.

Equation 11
$Ca(HCO_3)_2 + 2{*}RH \rightarrow 2H_2CO_3 + Ca\,R_2$

Equation 12
$Mg(HCO_3)_2 + 2RH \rightarrow 2H_2CO_3 + Mg\,R_2$

Note *R, In this and subsequent equations, represents the residual resin component.

Figure 20. **Diagram of de-alkalisation plant.**



(B) The water from stage A, now free from temporary hardness but containing carbonic acid, is passed downwards through a degassing column counter-current to a flow of air. The carbonic acid, which is only weakly associated, breaks down readily and CO_2 is driven off.

Equation 13
$H_2CO_3 \rightleftharpoons CO_2 + H_2O$

(C) The third and final stage comprises base-exchange plant. Water from the degassing column is treated with caustic soda to remove slight residual acidity and is then stripped of permanent hardness by sodium ion exchange.

Equation 14
$CaCl_2 + 2R\,Na \rightarrow CaR_2 + 2\,NaCl$

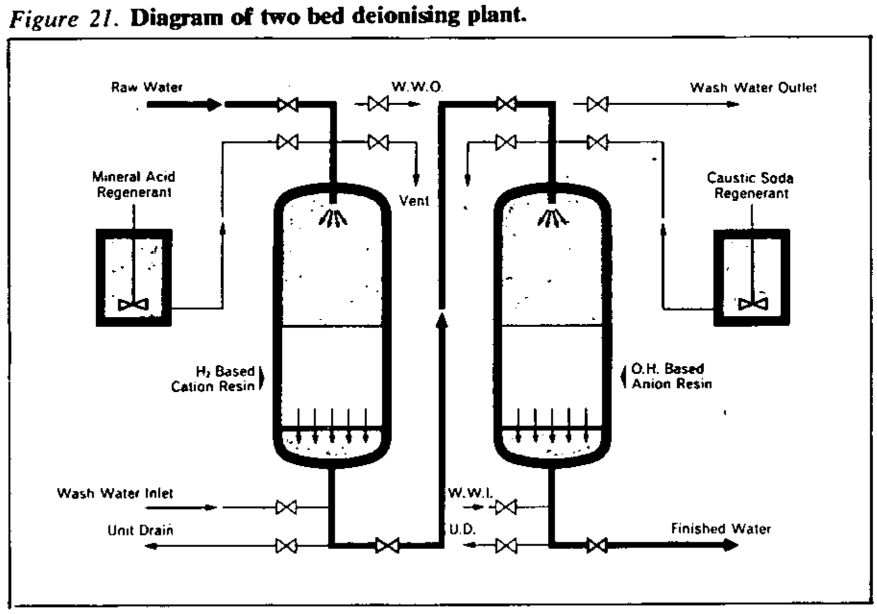
Equation 15
$MgCl_2 + 2\,R\,Na \rightarrow Mg\,R_2 + 2NaCl$

The resins used in the first and third stages are regenerated with mineral acid and sodium chloride respectively. The 'service' between regenerations depends entirely on the quantities of resins employed and may be calculated to suit the user's convenience.

Two bed system

The two bed system employs hydrogen based cation exchange and hydroxyl based anion exchange in series, cations — calcium, magnesium etc., are first removed by hydrogen exchange and the mineral acids so formed are then destroyed in the hydroxyl based anion exchanger. The two bed system is a complete demineralisation system in itself and requires no degassing tower.

Figure 21. **Diagram of two bed deionising plant.**



The two process steps are as follows:
(1) Hydrogen based cation exchanger. The strongly acidic exchanger replaces all cations in the raw water with hydrogen ions and strong acids are produced:

Raw Water containing			Cations exchanged for hydrogen and retained	Effluent contains
Bicarbonates	Ca)	$(HCO_3)_2$	Ca^{++}	Carbonic Acid $H_2(CO_3)_2$
	Mg)		Mg^{++}	Carbonic Acid $H_2(CO_3)_2$
	Ca)		Ca^{++}	Sulphuric Acid H_2SO_4
Sulphates	Mg)	SO_4	Mg^{++}	Sulphuric Acid H_2SO_4
	Na_2)		Na^{+}	Sulphuric Acid H_2SO_4
	Ca)		Ca^{++}	Hydrochloric Acid HCl
Chloride	Mg)	Cl_2	Mg^{++}	Hydrochloric Acid HCl
	Na_2)		Na^{+}	Hydrochloric Acid HCl
Silicic acid H_2SiO_3				Unaffected Silicic acid H_2SiO_3

(2) The second stage is provided by the hydroxyl ion based anion exchanger.

The effluent from the cation exchanger, containing the acids listed above, is passed through the anion exchanger in which the strongly basic anion resin removes the anions of the free acids, giving the hydroxyl ion (OH^-) in exchange:

Effluent from cation exchanger containing	Anions exchanged for OH^- and retained on resin	Finishing Water contains
Carbonic Acid H_2CO_3	CO_2^{--}	H_2O
Sulphuric Acid H_2SO_4	SO_4^{--}	H_2O
Hydrochloric Acid HCl	Cl^-	H_2O
Silicic Acid H_2SiO_3	SiO_3	H_2O

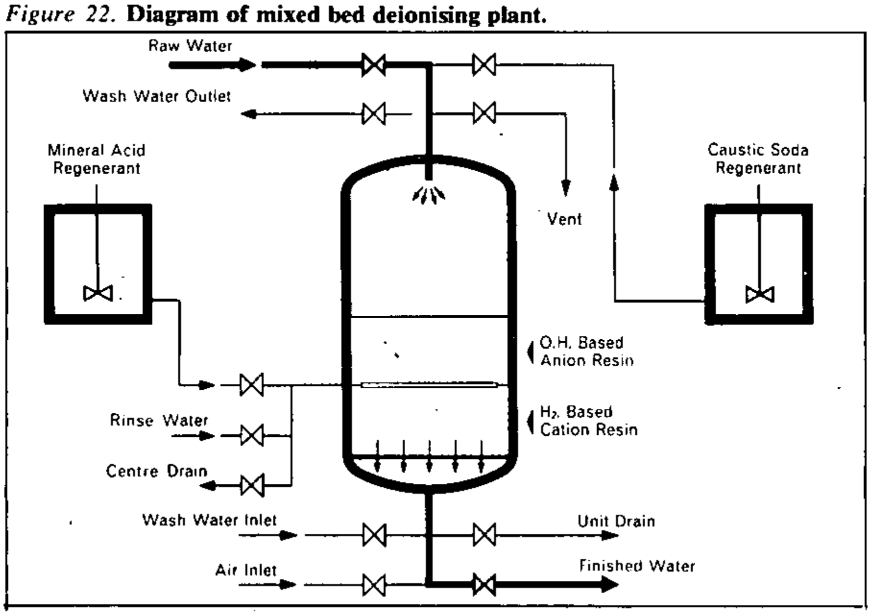
In theory, the finished water is pure. The first cost of this plant may be reduced by removing the CO_2 in a degassing tower installed between the cation and anion exchanger units.

Mixed Bed System

In this plant, the two resins, cation and anion, are accommodated in one bed, completely intermingled and so providing a high demineralising capacity. The unit is more complex in construction than a normal single bed, but the difference in density between the cation and anion exchangers is used to obtain separation into two layers. This aids in regeneration.

On occasion, more mixed bed units are installed, the additional units acting as 'polishers' where highly pure water for high pressure water tube boilers or for the preparation of pharmaceuticals is required.

Figure 22. **Diagram of mixed bed deionising plant.**



Strongly acidic cation resins and strongly basic anion resins are used for complete demineralisation, but specific water qualities may be attained by varying the characteristics of the exchangers. For example, if silica elimination is not required and other weakly ionised acids are not objectionable, a weakly basic anion resin may be used to be regenerated with sodium carbonate in place of caustic soda, so reducing the running costs.

Regeneration of the mixed bed to restore the resin capacity is carried out as follows:

(i) At the end of the service period, wash water is introduced at the bottom of the plant to backwash the resins. Dirt is removed and agglomerations broken down. After backwashing the resins settle, classified by density difference into two separate beds.

(ii) *Anion regeneration* (topmost bed). Caustic soda is introduced at the top of the vessel, flows evenly through the resin and leaves via the header at the interface surface via the centre drain. The anion bed is then rinsed with water to remove displaced ions and excess regenerant by the same path.

(iii) *Cation regeneration* (lower bed). Mineral acid in solution is introduced at the interface header and flows evenly downwards through the resin, leaving at the bottom of the vessel. The cation bed is then rinsed with water on the same flow path.

(iv) *Air mix.* The regenerated resins are fluidised by backwash water from the bottom of the vessel, and air introduced in the same direction. The resins are intimately mixed and then allowed to settle. The mixed bed is then rinsed downwards and put back into service.

De-aeration

Dissolved oxygen and carbon dioxide are primary sources of corrosion within boilers and associated equipment. Measures should therefore be taken to eliminate these hazards, and physical de-aeration is a good remedy. For water tube boilers, operating at the higher pressure, it may be necessary to follow up with chemical treatment of the feed water.

Solubility of oxygen, air and carbon dioxide in water, at any pressure will decrease as the temperature of the water rises. Scrubbing steam can therefore be used to impinge on heated droplets of water, which will provide a large area.

Pressure De-aeration

Figure 23 shows a storage type pressure de-aerator which consists of a horizontal storage vessel in which is mounted a de-aerating head. Feed water is introduced through spray nozzles, which divide the water into fine droplets. Steam is fed through a steam scrubber mounted in the storage vessel and passes upwards, countercurrent to the falling water spray. The feed water is thus subjected to a vigorous scrubbing action, and dissolved gases are almost completely removed, being released at the top of the de-aerating head. Steam entrained with these gases can be condensed in a direct contact condenser. The storage feature is not essential, but is often desirable.

This pressure de-aerator normally works at a pressure a little above atmospheric, with a corresponding saturation temperature, eg 3 psig (0.2 bar) 221°F (105°C).

Vacuum De-aerator

The normal range of feed water temperatures is, however, 140°F to 200°F. To treat the feed water to eliminate the dissolved gases, and produce feed water at the required lower temperature, a vacuum de-aerator can be used at a pressure below atmospheric.

The vacuum is set up by the use of a vacuum pump or a steam operated ejector, which extracts from the de-aerator the incondensible gases released from the water being treated.

Normal design of this type of de-aerator consists of a vertical cylindrical vessel having only a nominal storage capacity, as storage is not considered necessary with this type of equipment. The water to be treated enters the de-aerator through a single spray nozzle of the fixed orifice type designed for the particular flow, to give the maximum of fine droplets and so the maximum surface area.

An extraction pump is necessary to draw from the de-aerators and deliver to the pipework supplying feed water to the boiler feed pumps. Any feed water in excess of the feed pumps demand is recirculated back to the feed water inlet to the de-aerator so that the flow into the de-aerator is kept at a constant rate. High and low level alarms should be provided to ensure that an adequate supply of treated water is available.

Figure 23. **Pressure de-aerator.**

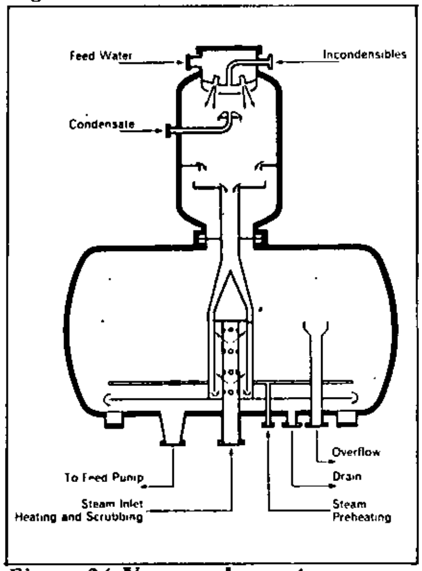
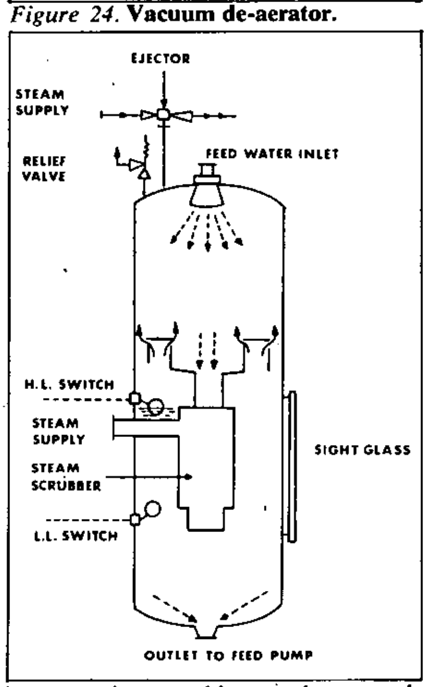


Figure 24. **Vacuum de-aerator.**



Reverse Osmosis[9]

Osmosis is where two solutions of differing concentrations are separated by a semi-permeable membrane, solvent will pass through the membrane from the dilute to the concentrated solution. For any given solution there is, however, a maximum differential pressure which can exist across the membrane, known as the osmotic pressure. If a pressure greater than this is exerted on the concentrated solution the flow is reversed and solvent passes from the concentrated to the dilute solution, this is 'Reverse Osmosis'. In practice a high pressure pump is used to separate the feed water into two streams, a fine water stream and a concentrated stream carrying the dissolved salts.

The water supplied to the reverse osmosis unit should be pre-treated by base exchange softening in order to avoid possibility of fouling the membrane.

The advantage of this method of water treatment is that, apart from the cost of salt for regeneration of the base exchange unit, there are no other chemicals to provide, so running costs are comparatively low. The initial capital cost of the equipment is, however, high.

Internal Treatments 'B'

Chemicals may be added to the feed water, usually after some previous external treatment in order to improve the quality and remove gases.

For reduction of O_2, or oxygen scavenging the choice of chemicals is mainly between sodium sulphate, Na_2SO_3 or hydrazine, N_2H_4.

Sodium sulphite reacts with oxygen and forms sodium sulphate according to the equation

$2Na_2SO_3 + O_2 = 2Na_2SO_4$.

This reaction is slow and can be inhibited by certain constituents present in some waters. In order to remove all oxygen there must be excess of sulphite over and above the theoretical amount of eight parts by weight of sulphite required to remove one part by weight of oxygen.

The recommended excess varies between 20-100 ppm.

The main disadvantage of this is that the sulphate so formed increases the TDS necessitating more frequent blow down (there is evidence of this at Fulbourn Hospital).

Hydrazine, however, has the advantage that the products of its reaction with oxygen are water and nitrogen so the dissolved salts are not increased: ie, $N_2H_4 + O_2 \longrightarrow N_2 + H_2O$.

Again the reaction is slow but the rate increases appreciably with increase of temperature. For best results the hydrazine is added after de-aeration when the water temperature is of the order of 100°C.

The cost is less than sodium sulphite and it is more efficient in oxygen removal.

Disadvantages are that catalytic or thermal decomposition of hydrazine gives rise to ammonia according to:

$$2N_2H_4 \longrightarrow H_2 + N_2 + 2NH_3$$

$$\text{or } 3N_2H_4 \longrightarrow N_2 + 4NH_3.$$

Copper or magnetite will accelerate the decomposition while copper also gives rise to nitrous oxide, N_2O (laughing gas).

Hydrazine is also toxic but requires no more care in handling than that necessary for concentrated acids or alkalis.

These disadvantages, however, are such that its use is generally precluded from hospital boiler use, especially where a kitchen is fed with live steam.

Caustic cracking has been mentioned but it is not generally a problem with modern all welded shell boilers. Care is, however, needed if a treatment is chosen which requires the addition of caustic soda, NaOH, eg, de-alkalisation, as depending upon the method employed to secure the boiler fire tubes to the tube plates, a concentration of NaOH can build up in the crevice of swaged-in tubes, leading to caustic embrittlement.

Methods employed for control of caustic cracking will not be covered as, excepting the instance above, the problem generally does not arise with 'all welded' boilers as used in the Health Service.

Internal treatments of boilers to prevent scale formation are available. Below 150 psi boiler pressure sodium carbonate may be used, but at pressures in excess of this sodium phosphate is used. In the case of addition of calcium carbonate, non-alkaline hardness is converted to alkaline hardness and is precipitated as calcium carbonate, which may be dispersed with organic sludge conditioners. Part of the sodium carbonate is hydrolised by heating into sodium hydroxide, and this is available to precipitate magnesium as the hydroxide.

The sodium phosphate, generally trisodium phosphate or hexametaphosphate, hydrolyses in the boiler to form orthophosphate, which combines with calcium, the resulting sludge being again dispersed with organic conditioners.

Foaming has already been described. Anti-foaming agents are used; these usually consist of a long chain polyoxide or polyamide compound which breaks down the foam layer and so reduces carry-over.

Commercial products are available which are a mixture of the chemicals mentioned, these control to a certain extent scale and sludge formation and also incorporate an anti-foaming agent.

Treatment for Condensate Return Lines

As outlined, condensate return lines are subject to corrosion due to the oxygen and carbon dioxide. Both gases may be present in solution and CO_2 may also be in the combined form as bicarbonate. Dependent upon the treatment of the feed water some proportion of either or both of these gases may be present upon condensation of the steam.

When steam condenses, oxygen and carbon dioxide dissolve, producing a dilute carbonic acid solution containing oxygen. (This accounts for the low pH of the Fulbourn condensate). This solution is very aggressive, attacking steel and copper return pipes.

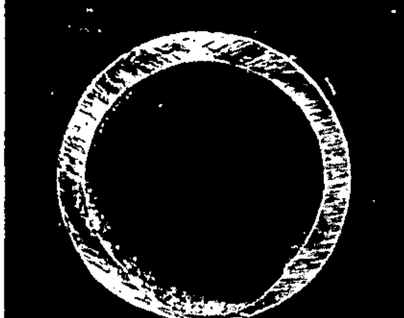
If oxygen predominates, the metal tends to be pitted and if carbon dioxide predominates it will be channelled out as grooving. Both types of attack are frequently encountered together.[14]

Figure 25 is given for interest. Here the section was taken from the Fulbourn hot water service pipe line; the pitting, indicative of the presence of oxygen, is clearly shown.

Figure 25.

Figure 26 is a section of steel condensate line, showing the reduction in annular section due to the aggressive possibly predominantly carbonic acid condensate solution.

Figure 26.



Volatile Amines

These may be used to prevent corrosion in condensate return pipes. They fall into two broad classes.

Neutralising Amines[7]

These are added to the feed water and distil over with the steam. Provided sufficient quantities are added the CO_2 is neutralised. The organic compounds in common use are cyclohexylamine and morpholine. A little in excess of that required for neutralisation is added in order to raise the pH of the condensate to 8.5. Continuous dosing is normally carried out, this may be done with any other chemicals required for conditioning. Water with a high bicarbonate alkalinity would require large quantities of the amine and would prove expensive to treat by this method.

Neutralising amines are, however, poisonous and their use in hospitals would not be considered.

Filming Amines[7]

These reduce the possibility of corrosion by forming a molecular film on the internal surface of the pipe preventing the oxidation or attack by aggressive condensate. The film also promotes dropwise condensation and improves the efficiency of heat transfer.

The degree of coverage or wetting of the metal surface is a function of the strength of the metal-amine bond and the orientation, shape and size of the molecule.

Aliphatic amines with straight chains of carbon atoms are more effective than those with branching of the non-polar part of the amine. The length of the carbon chain is also important, amines with a chain length of 10 to 18 atoms being most efficient.

Octadecylamine having 18 carbon atoms is most often used and has the added advantage of a lower toxicity than other filming amines. It is generally applied by injection of the acetate salt into the steam or condensate lines by a proportioning pump.

Concentration may be from 0.5 ppm to 25 ppm, with an average level of concentration of 5 ppm. It should be noted, however, that *Hospital Technical Memorandum No 6, DHSS* revised 1970, states that only where the concentration can be guaranteed not to exceed 3 ppm at any time may the boiler steam containing octadecylamine be used for food processing in wet steaming ovens, where the boiler steam is in contact with the food. The allowable concentration is reduced to 2.4 ppm where deposits of octadecylamine may be left when sterilising instruments, fluids, babies' feeding bottles, etc.

Thorough cleansing of the condensate lines is desirable prior to the introduction of filming amines to existing installations, as the film forming inhibitors have strong detergent properties, and loosened corrosion deposits will cause blockages and possible malfunction of steam traps and other equipment.

The Cost of Maintenance and Replacement of Pipe Work Due to Corrosion at Fulbourn and Ida Darwin Hospitals

For the 12-month period ending May 1977, some £7,000 was expended on the replacement of corroded condensate pipe lines. This figure includes a £4,000 maintenance contract for the renewal or copper pipe work in the Ida Darwin calorifier room.

As has been previously stated, the original copper pipe condensate lines have, where possible, been replaced with mild steel. These pipes corrode out very rapidly, in many cases within six months of renewal.

From the above figures some £3,000 is spent annually on this exercise, the cost of the inconvenience, and often damage to other plant and equipment, cannot be quantified.

The evidence indicates that the present water treatment at Fulbourn and Ida Darwin hospitals is not satisfactory for the suppression of the condensate line corrosion. This is shown in the water analysis where the condensate pH is down to 6.0 or 5.6. It seems clear that this is due to the alkali hardness being converted to CO_2 in the boiler under the action of heat as described above. The CO_2 has the effect of reducing the pH by the formation of dilute carbonic acid, a very aggressive condensate.

The following sections outline the alternative methods of overcoming the problem together with the economic consequences.

Review of Available Methods of Overcoming Condensate Line Corrosion

Quotations were obtained from various commercial water treatment firms for the cost of equipment that they recommended for the treatment of the boiler feed water for Fulbourn and Addenbrookes hospitals.

Fulbourn Hospital

Firm A — De-alkalisation

This firm recommended de-alkalisation plant.

The costings did not take into account the maintenance costs of condensate pipe replacement.

Basic cost of complete plant supplied to site: £8,290 + £713 for a raw water break pressure tank and booster pump = £9,003 total.

To this must be added the cost of installation and commissioning.

Installation is estimated by the manufacturer of the equipment to take two to three days, for a two-man team this equals £200 and commisioning is put at £100 plus travelling expenses, allowing for £400 for installation and commissioning.

The total cost is £9,400.

This figure is used in the economic assessment made in the next section.

Firm B — Internal Treatment

This firm submitted a report and the results of water analysis, samples being taken for raw water, softened water, condensate return, actual feed water and boiler water.

This firm could only make recommendations for the use of their chemicals for internal treatment, and, as will be noted from the extract from the quotation given in the appendix, they did not claim to overcome the condensate line corrosion problem solely by the use of internal treatment. They recommended the use of a de-alkalisation plant or amine treatment, suggesting that a heat exchanger be used for the kitchen requirements, so that a treatment involving a blend of neutralising and filming amines could be used for the remainder of the system.

Alternative Proposals

Prices were obtained for grades of high temperature GRP pipe manufactured in the USA under the trade name of 'Fibercast'.

The manufacturer claims that the material will withstand temperatures of up to 300°F (150°C) which would be suitable for use in the areas where the corrosion is most severe.

The estimated costs for the use of this material in those areas in the Fulbourn and Ida Darwin hospitals is given in *Table I*.

Also given for comparison are the costs of alternative materials which could also be used in the areas where the corrosion is most severe.

These are 90/10 Cu/Ni and stainless steel ASTM 316. The cost for copper and mild steel pipe is also given so that the comparison may be made.

Table I

Material	Nominal Pipe Size 1″	1½″	2″	3″
COPPER Supplied in lots of 100m length	£1.03/m	£1.94/m	£3.33/m	£4.75/m
MILD STEEL Black heavy weight screwed and socketed	£0.58/m	£0.89/m	£1.25/m	£2.17/m
CUPRO NICKEL 90/10	£5.00/m	£4.90/m	£6.50/m	£11.50/m
STAINLESS STEEL ASTM 316 18% Cr 10% Ni 2-3% Mo	£11.43/m		£19.00/m	£31.50/m
FIBERCAST OG 2025 Up to 250°F		£8.20/m	£9.50/m	£12.00/m
FIBERCAST RB 2530 for use up to 300°F			£11.30/m	£13.50/m

(Material costs — mid-1977).

Addenbrookes Hospital, Cambridge

Condensate line corrosion also occurs in this hospital built only five years ago.

Water treatment at the hospital consists of softening some raw water by the base exchange method and some by de-ionisation, basically of the cationic type. The resultant treated waters are 'blended' in the proportion of three parts de-ionised to one part base exchange and are fed to a pressure type de-aerator.

Condensate corrosion occurs mainly in the kitchen area of this hospital and it was thought that this could be due, in part, to the preparation of special diet foods in steaming ovens. This, however, is not the case, as condense, from such equipment is fed direct to waste. The most likely cause seems to be the discontinuation of base exchange softening by the Cambridge Water Company. The alkaline hardness is not reduced sufficiently, so this changes to CO_2 when heated.

It is not clear why only the kitchen area condense mains are most severely affected, but it could be due to the high steam usage in this large district general hospital when meal preparation is being carried out, the condensate pipes being at high temperature for a period of time, followed by prolonged periods out of use. The resulting cooling and possibly only partial draining of the pipes is probably a factor in the corrosion situation.

The condensate main pipes in this hospital are kept 'full' all the time, which is probably why little trouble has been experienced due to corrosion. Firm A recommended a reverse osmosis plant for the water treatment for this hospital.

The selection of their plant was based upon a comparison of running costs for a de-mineralisation unit against those for the reverse osmosis plant.

Firm C submitted a quotation for a two-bed de-ioniser plant, this plant is automatically regenerated so labour costs of operating would be low.

Recommendations for Replacement Steam Traps

Mr R. Bartlett, service manager, and Mr B. G. A. Burrows, regional engineer of Spirax Sarco Ltd, visited Fulbourn hospital. They were shown the samples of failed steam trap parts previously described, and were also able to inspect the steam and condensate installations.

The acidity of the condensate was felt to be the primary cause of rapid failure, using malleable iron steam trap bodies with mild steel internal parts.

The recommendation was for the replacement of steam traps having cast iron bodies and stainless steel internal parts.

The representatives of the firm also demonstrated how dezincification had occurred on the brass strainer screens of the traps inspected. The screens had lost virtually all their strength and were very easily crushed. This evidence is consistent with the conditions as already described, preferential attack in soft water containing CO_2.

Two theories are existent,[11] either that zinc dissolves leaving the copper behind, or that both metals dissolve and copper is redeposited. Again the recommended replacement is stainless steel. The analysis of the condensate supported the theory.

Regarding the replacement of floats for the Ogden Automatic Pump, one was in mild steel and the other in stainless steel, the stainless steel one being additionally coated with 'Rotoguard', a compound designed to seal sprayed metal coatings. The manufacturers, the Eutectic Co Ltd, of Feltham, do not think the application will help the situation, but should do no harm.

The recommendations of replacements will be implemented as other steam traps fail in service.

Economic considerations of alternative treatments, and/or of different materials

As has been indicated, the main cause of the condensate line corrosion in these hospitals is due to carbonate hardness of the raw water changing to sodium bicarbonate with the evolution of carbon dioxide under the action of heat in the boiler. The steam carrying the CO_2 in dissolved form, which upon condensation becomes carbonic acid. This effectively reduces the condensate to a dilute acid which, as has been shown, is very aggressive to the pipe lines carrying it.[14]

The present plant at Fulbourn hospital consists of a base exchange unit with internal treatment by Nalfloc.

The base exchange unit uses NaCl at the rate of 6000Kg per 64 days the cost being £190 for 8000Kg.

This gives a total cost of *£815 per annum.*

Nalfloc A310 powder (sodium sulphite) is used at the rate of 70 lbs per week at 25p per lb, this amounts to *£910 per annum.*

Nalfloc A724 powder (sodium polyphosphate) is used at the rate of 14 lbs per week, which at a cost of 35p per lb, gives an *annual cost of £260.*

To these costs must be added the annual maintenance bill for condensate pipe renewal of *£3,000.*

The *total cost being therefore £4,985.*

Say £5,000 for ease of working.

The de-alkalization plant would cost, as previously reported £9,400 and using figures supplied by Firm A for savings on cost of fuel and water due to reduced blow down are £1,500 per annum. The total savings per annum should amount to some £6,500, is assuming that the internal treatment will no longer be necessary. In view of the known difficulties regarding scale build up in relation to the tube/tube plate interface, the addition of some scale reducing additive could well be required.

Thus, allowing for the additive, even with the full de-alkalization plant, of the Nalfloc A724 powder, the total cost savings still should be in the region of £6,200 per annum.

However, from the above the capital costs of installing a de-alkalising plant would be well covered in two years, on current prices.

The use of any of the alternative materials given in *Table 1* would reduce the maintenance costs due to the longer life expectancy of such materials, but of course, would not solve the problem of acidic condensate.

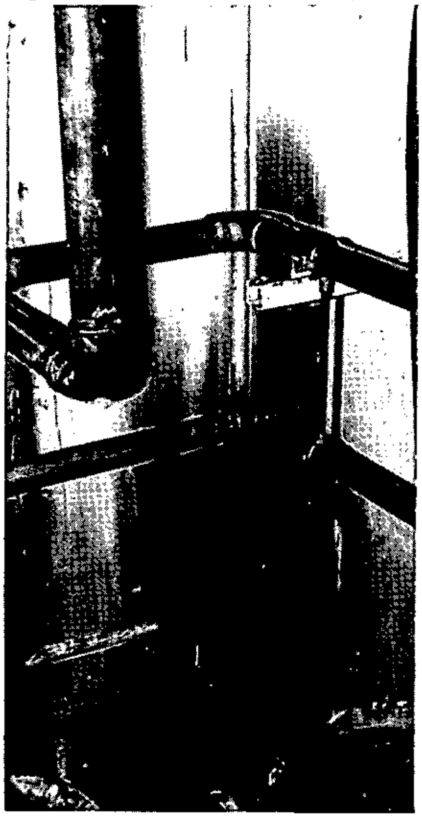
The savings to be made by only using such measures would be small indeed compared to the savings outlined for a complete de-alkalisation plant.

As will be appreciated the figures given can only be a guide as, due to the corrosion already taking place within the condensate system, some maintenance would have to be carried out for some time.

The corrosion deposits would also still continue to break away, causing some erosion damage to the internal surfaces of the pipe lines at bends and curves.

The pipe work in the receiver chamber at the Ida Darwin hospital is shown in *Figure 27.*

Figure 27.



The sharp right angle bends in the pipe lines indicate poor pipe fitting practice, especially in view of the known problems with the pipe work in the hospital.

All bends should be made with as large a radius as possible in order that any corrosion products, being swept along by the condensate do not erode the internal surfaces of the pipes.

Expected Final Solution

As a result of this study, the Area Works Officer for the Cambridge Area Health Authority, has now placed orders for the supply of a complete de-alkalisation plant for the treatment of the boiler feed water at Fulbourn and Ida Darwin hospitals.

This, as has been indicated, should overcome, if not fully, at least to a great extent, the serious corrosion problems encountered in the hospitals.

A de-gassing tower is being installed at the Addenbrookes hospital.

The system here will then consist of de-ionisation (all raw water) — de-gassing — base exchange and de-aeration. Again this system should ensure that all carbonate hardness is eliminated and that all CO_2 is driven off before reaching the boilers.

This should solve the corrosion problems encountered.

Brief Case History of Water Treatment at Little Plumstead Hospital, Norwich

This is a large 547 bed Mental Handicap hospital on a widely dispersed site.

The condensate drains by gravity to the plant room and is pumped back to the boiler house, a similar arrangement to that in operation at the Fulbourn and Ida Darwin hospitals.

The boiler feed water was treated chemically, the condensate lines being protected by filming amines. This treatment was, however, stopped in 1968, and the following is a record of treatment from this time.

1968-1972 Nalfloc continued treatment apparently using only their A724 powder which is a sodium polyphosphate controlling scale and sludge formation and has an anti-foaming agent incorporated.

1972-1975 An all liquid treatment was used, supplied by CIBA-GEIGY.
The chemicals being:

Belloid FW 41 — A complex chemical formation used as a scale conditioner.
Belgard CLP — cyclohexylamine — a volatile neutralising amine — not now allowed for use in hospital steam systems.
Bellauxine CD — Anhydrous sulphite for oxygen scavenging.
Bellauxine P — A polyphosphate for sludge and antifoam.

1975-1977 Botan Ltd, supplied chemical treatment FTI, sodium sulphite and monophosphate for oxygen scavenging, replaced during the period of treatment by FT3 which is sodium sulphite and sodium hydroxite.

P18, a polyamide for its antifoaming properties replaced subsequently by PA6, which is a polyacrylate, really a sludge dispersant.

FT75 was also used, which is a sodium sulphite with polymer addition, virtually FT1 with added properties.

At present the main condensate pipework is being renewed in copper.

Filming amine treatment has been carried out since July 1977, the amines are injected into the steam header. Some slight trouble has been experienced with debris in the equipment but this will not be a problem when all the condensate lines have been renewed.

The concentration of amines as tested in the condensate return at the hot well is 0.2-0.5 ppm.

As has been found in Fulbourn there is some evidence of erosion corrosion due to corrosive products being swept round the system by the condensate.

The boilers at Plumstead are protected by internal treatment, Nalfloc A724 sodium polyphosphate, controlling scale, sludge and foaming.

Conclusions

The main cause of condensate pipe line corrosion in the hospital service appears to be the presence of CO_2 in either dissolved or gaseous form.

It has been shown that base exchange water softening does not affect the temporary or carbonate hardness of the treated water, the bicarbonates change to CO_2 under the action of heat, which passes into the steam to condense as carbonic acid.

While the Fulbourn and Ida Darwin hospitals are going to install a full de-alkalization unit which will theoretically solve the problem, there could still be problems with the system as some small amount of carbon dioxide and oxygen will still be present.

The use of one or more of the alternative materials suggested for the pipework at the points where the corrosion is most severe could well need to be considered.

The use of a full demineralising unit, de-gassing tower, base exchange and de-aeration at Addenbrookes hospital should, however, solve the problem completely (with suitable internal treatment).

At Little Plumstead hospital, the return to the use of filming amines, if the experience of the past is to be relied upon, should stop the condensate corrosion in this hospital.

It will be interesting to see in the future which hospital has taken the best solution.

As will have been appreciated throughout, the use of certain measures for overcoming this problem whilst being viable for commercial undertakings are not suitable for use in a hospital, due to possible contamination of food or problems with sterilising.

However, much information has been gathered on this problem and can be used in order to evaluate the treatment necessary for other hospitals and conditions.

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[3]**Spirax - Sarco:** *Ogden Automatic Pump.* Pamphlet 1G.

[4]**Spirax - Sarco:** *Ogden Open Top Bucket Steam Trap.* Pamphlet SE/1.

[5]**Spirax - Sarco:** *Drayton Inverted Bucket Steam Trap.* DWG. T455/1. 1976.

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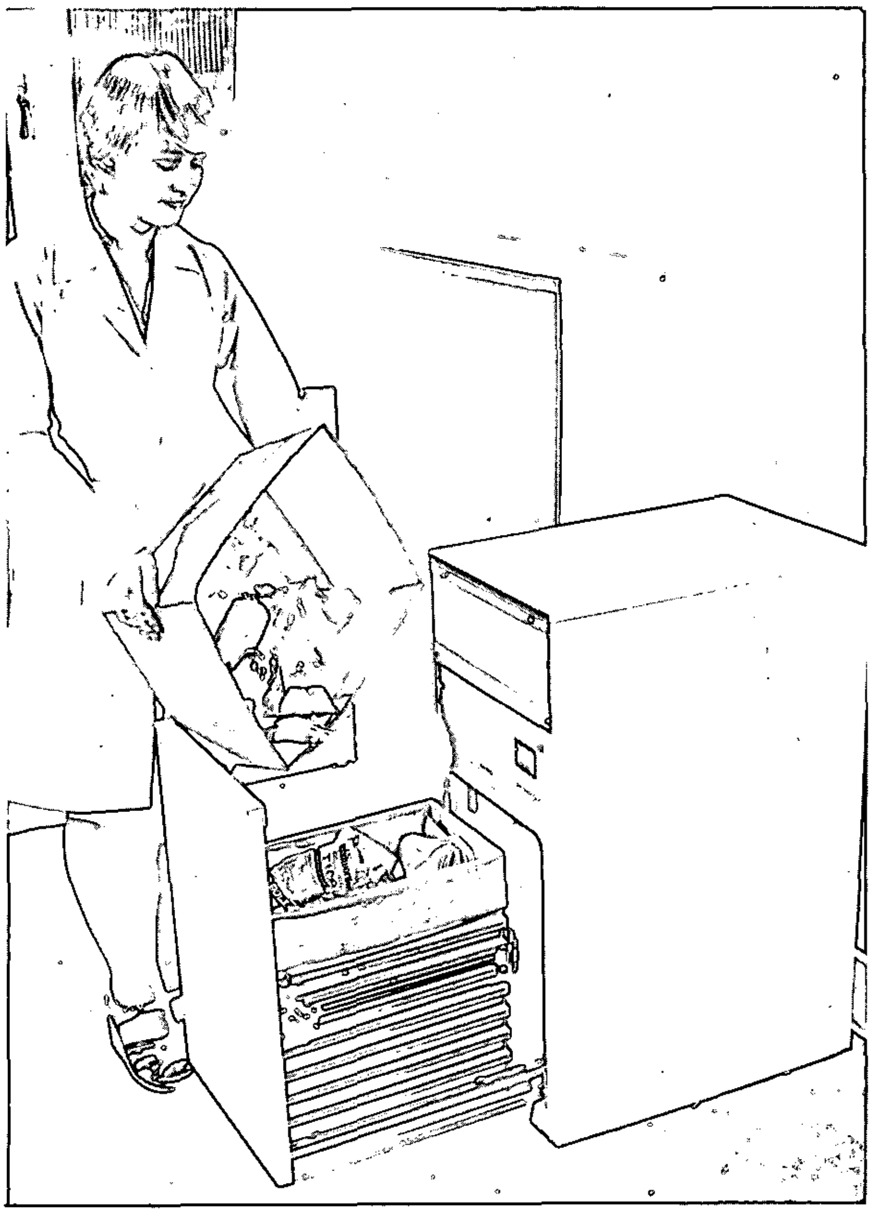
Product News

New Compactor for Bulk Kitchen Waste

The mechanical compression of rubbish and its subsequent storage and removal in neat paper sacks is a new method of solving problems of handling and hygiene involved in waste disposal.

Reed Medway Sacks Limited are to market a machine which, it is claimed, will compress the contents of three average dustbins into a 16 × 16 × 9in disposable bag. Known as the 'Trash Masher' and imported by Heatrae Catering Equipment Ltd from the USA, this new compactor has a simple electro-mechanical screw action. No bigger than a washing machine, it will plug into any 13 amp socket. Its main application is the disposal of commercial and industrial kitchen waste (including tin cans and bottles) and its average compression ratio is 3 : 1. The two-ply polythene lined construction of the disposable paper sacks gives them considerable wet strength.

Reed Medway Sacks Limited, Aylesford, Maidstone, Kent. Tel. 0622 77855.



Safety Requirements for Catering Equipment

BS 5314 *Gas Heated Catering Equipment,* published by BSI, is a new specification that gives, in a number of parts, the saftey and performance requirements and associated tests for a range of gas-heated catering equipment. Part 4 *Fryers* is the latest to appear. It relates to fryers of the type used in restaurants and catering establishments for deep frying. It does not cover frying ranges like those generally used for the preparation of fried fish and chips.

The requirements cover gas soundness, heat input, combustion, ignition, flame stability, appliance flue outlet (and draught diverter), fire hazard and controls as well as construction and design. Performance requirements are detailed and some additional requirements for construction, design and finish are provided.

BS 5314 covers equipment burning natural, town and liquefied petroleum gas, and supersedes equivalent sections of BS 2512 and BS 4104. Six other parts have already been published; they deal with ovens, boiling burners, grills, steaming ovens, bulk liquid heaters and water boilers.

BS 5314 may be obtained from BSI Sales Department, 101 Pentonville Road, London N1 9ND. Price £4.70.

Full Range of Teledyne Gas Analysers now available in the UK

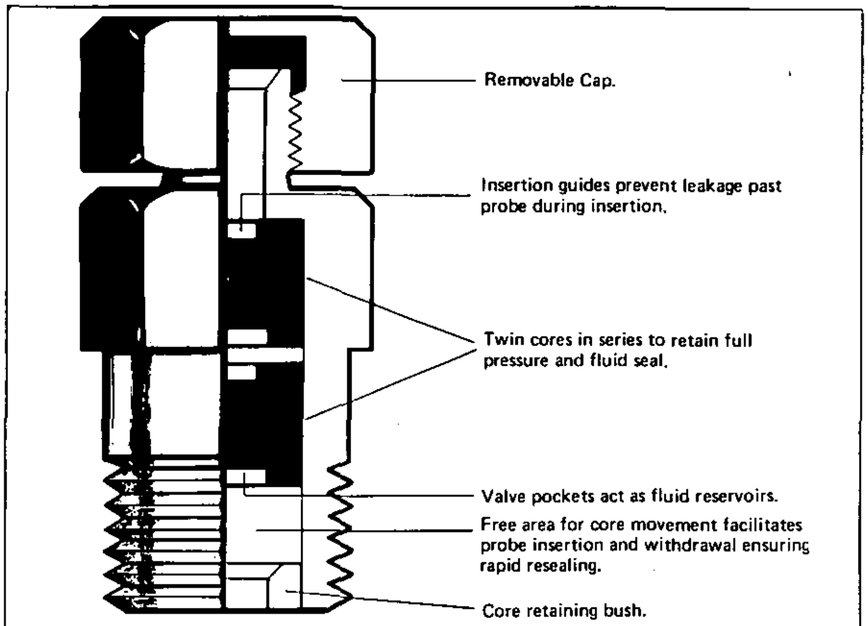
A comprehensive range of Teledyne Flue Gas Analysers is now available from Analysis Automation Limited of Oxford. The range of analysers, manufactured by Teledyne Analytical Instruments, is designed to provide accurate information on the efficiency of combustion processes, so allowing closer control, and therefore lower fuel costs. Analysers are available for oxygen, or oxygen and combustibles and the range includes portable instruments for spot checks, and complete systems designed for permanent installation and continuous unattended operation. All analysers provide rapid direct readout by front panel meter.

The portable instruments available are the Model 320P oxygen analyser and the Model 980 oxygen and combustibles analyser. Both units are lightweight, compact and robust and operate from internal rechargeable batteries. Operation is straightforward, with a single switch providing battery status check, and on/off control. Sampling pumps are built-in, and an air dilution system is incorporated in the combustibles section of the Model 980. No external sampling system is required other than a metal probe.

Sensitivity of the Model 320P and Model 980 is 0-5%, 0-10% and 0-25% oxygen in the standard range. The Model 980 sensitivity in the combustible section is 0-5% (Methane equivalent).

The continuous analyser models incorporate comprehensive sample conditioning facilities. The Model 9500 is the standard oxygen analyser system, the Model 9700 measuring both oxygen and combustibles. The sampling systems have been carefully designed to reduce maintenance requirements and ensure long-term operation on all types of process. The analysers have output signals for chart recorders and optional alarm facilities. For hazardous area operation special Teledyne analyser models are available.

Analysis Automation Limited, Cherwell Boathouse, Bardwell Road, Oxford OX2 6SR. Telephone: (0865) 53713. Telex: 837509.



Pat. No. 1383880

New Self Sealing Test Plug

Binder Engineering Ltd, have introduced Twinlok, a fully patented self sealing test plug which has been developed from their Universal test plug. The Twinlok test plug can be screwed into a threaded socket or pipe fitting in any vessel or piping system, thereby providing a convenient method for introducing a probe into the system to obtain temperature and pressure readings quickly and easily, to take samples of the contents, to inject small quantities of fluid or to release air from the system.

For pressure checks the probe is a hollow 4mm diameter stainless steel needle which is fitted to an adaptor to take a standard pressure gauge of the appropriate range of calibration. Alternatively, the probe can be used in conjunction with a manometer, a differential pressure gauge or transducer. The temperature probe can be any suitable bimetallic element, thermistor, thermocouple or resistance element used with an electric or electronic indicator. The Twinlok test plug will accept probes up to 4mm in diameter and they do not need to be lubricated.

Safety is assured from leaking or jetting when the probe is withdrawn, by the presence of two unique self sealing moulded cores of synthetic rubber concealed in the brass housing which is ¼in BSP size and 35mm in length. Plugs with cores to suit various temperature and chemical resistance ratings are available.

Plugging in one test instrument only at any convenient place saves the expense and potential damage to permanently installed instruments. At the same time it reduces the effect of multiple instrument error and allows systems to be balanced with a greater degree of accuracy, thus achieving optimum performance and energy saving as well as prolonging the life of the system.

Binder Twinlok self sealing test plugs are inexpensive to install and can be used with the complete range of Binder instruments in all plant and pipeline systems. They can be fitted to hot and chilled water systems, heat exchangers, cooling coils, pumps and all equipment where temperature and pressure differentials are needed.

Binder Engineering Co Ltd, The Looe, Reigate Road, Ewell, Surrey KT17 3DB. Tel. 01-394 0135.

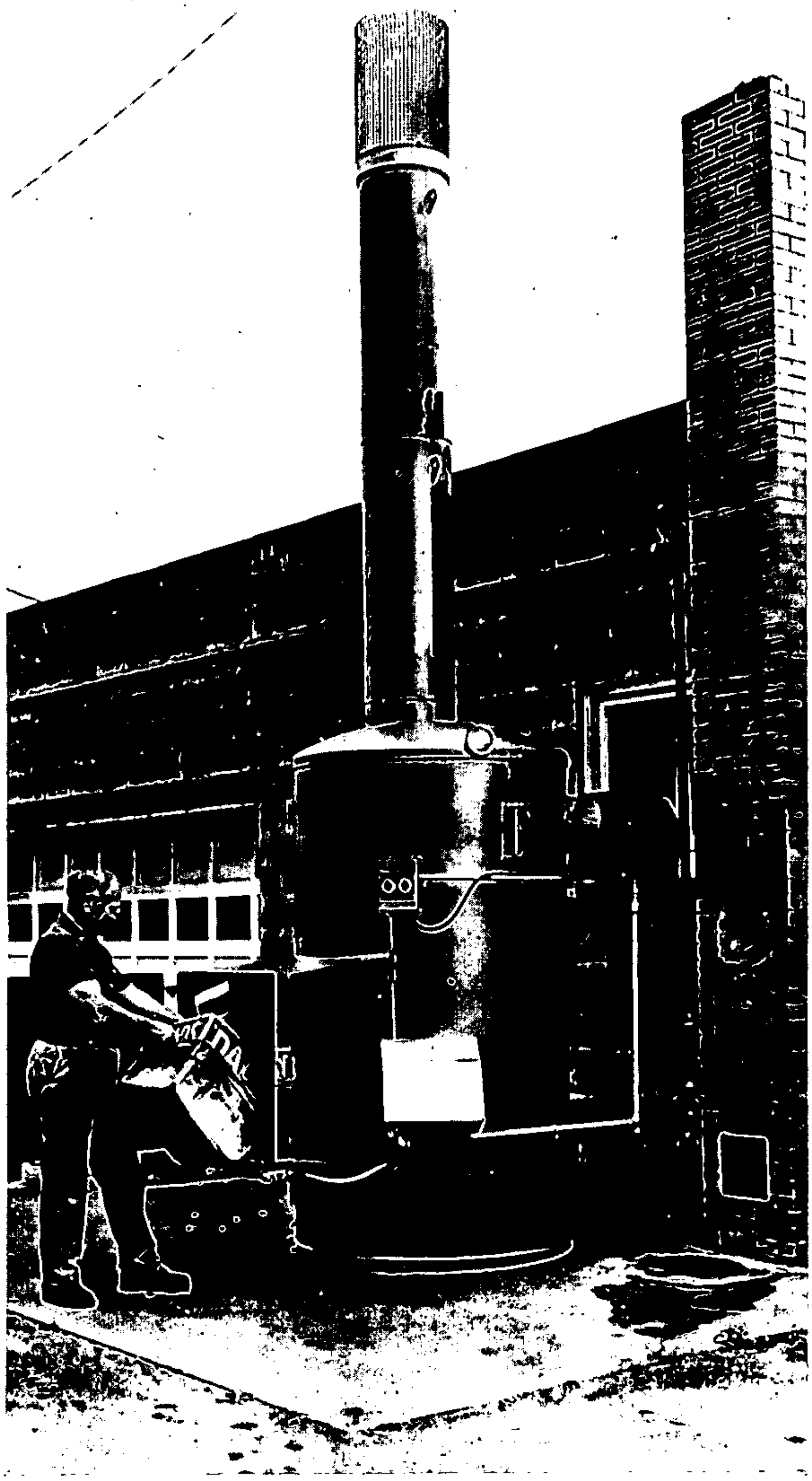
New Line of Smoke-free Incinerators

Beverley Chemical Engineering of Billingshurst have announced the introduction of a new line of smoke-free incinerators, known as the Beverley COMTRO range.

They can handle all the usual types of solid waste produced by Industries and Institutions including high moisture garbage and pathological waste. They will be made under licence from the Sunbeam Equipment Corporation of Pennsylvania.

The new range comprises nine standard sizes of packaged units with burning capacities from 100 to 3,000 pounds per hour.

Beverley Chemical Engineering Co Ltd, Billingshurst, Sussex RH14 9SA. Telephone: 040-381 2091.



Directory Aids Identification and Procurement of Specs, Standards, Research and Technical Reports

The Directory of Engineering Document Sources (DEDS) is now available from London Information, at £39.50.

DEDS is not only a source of identifying current issuing authorities for obtaining US Government agency documents but also industry associations, learned societies, educational institutes and many non-American English-language institutions.

The Directory is designed primarily for use by a person who knows a document identification number but not the procurement source. There are four sections. The first lists over 8,000 engineering / scientific / management publications giving the document series name, the originating organisation, the index to the document series and the source of the document. Section two lists about 500 indexes to the document series and the sources of the indexes. The third section gives over 3,500 international sources for document procurement and the last section is an extensive table of US Government Agencies showing where documentation and standardisation originate. All the sections are fully cross-indexed and designed for fast, accurate use.

London Information has on-line access to the publishers' data bank in California and can supply any of the current publications listed in DEDS within a matter of days from receipt of an order.

The Directory of Engineering Document Sources is published every two years and London Information offers a seven-day no-risk free trial with a guarantee of a full refund if the book is returned undamaged within seven days.

Directory of Engineering Document Sources (second edition). Price £39.50, 260 × 210 mm. 300 pages.

Sole Agents in the UK: London Information (Rowse Muir) Ltd, Index House, Ascot, Berkshire SL5 7EU. Tel. 0990 23377.

Classified Advertisements

APPOINTMENTS AND SITUATIONS VACANT

BIRMINGHAM AREA HEALTH AUTHORITY (TEACHING)

WEST BIRMINGHAM HEALTH DISTRICT

Engineering Works Officer

(District based)

(Sector Engineer Grade: Salary scale £4,870-£5,761 inclusive of supplements)

The man or woman appointed will be accountable to the District Engineer for the general management of the Engineering Services for the West Birmingham Health District, and have special responsibilities for contract procedure and minor new works. The successful applicant will be assisted by a team of three Hospital Engineers and their Assistant Engineers. Applicants should have a good knowledge of all aspects of engineering associated with Health Service buildings, together with demonstrated managerial ability, and be able to work effectively with colleagues of other disciplines.

Minimum qualifications: HND or HNC in Electrical or Mechanical Engineering together with a Technical College's certificate in Applied Heat, Applied Mechanics (Electrical Engineer) or Electrical Engineering (Mechanical Engineer) and Industrial Administration. Other DHSS approved qualifications will be considered.

Hospital Engineer

Dudley Road Hospital (868 beds)

(Salary scale £4,101-£4,639 inclusive of supplements plus £183 Special Responsibility Allowance)

The successful applicant (male/female) will be based at this busy District General Hospital, and be responsible to the Engineering Works Officer for all engineering services, which include Boiler House, Laundry, Hospital Sterile Supplies Unit and emergency services. The officer will be assisted by three Assistant Engineers. Applicants should have completed an Electrical or Mechanical Apprenticeship. The qualifications for this post are the same as for the Engineering Works Officer post (see above).

Further information for both appointments may be obtained from: Mr. D. L. Hall, District Engineer. Tel. 021-554 3801 Ext. 4838.

Application forms and job descriptions available from the Area Personnel Officer, Birmingham Area Health Authority (Teaching), Alpha Tower, Suffolk Street, Queensway, Birmingham B1 1TP. Tel. 021-235 4466.

Closing date: 13th March, 1978.

King's Lynn Health District

A. Assistant Hospital Engineer

(Mechanical)

B. Assistant Hospital Engineer

(Electrical)

C. Assistant Building Supervisor

Suitably experienced and qualified persons are required for the above posts on the staff of the District Works Officer at the new District General Hospital, King's Lynn. Minimum qualification is ONC in the appropriate subject.

Salaries A and B £3,063 (x6) to £3,507 plus £312 non-enhanceable supplement, plus £153 supplement.

Salary C £2,697 (x5) to £3,102 plus £312 non-enhanceable supplement, plus £134 supplement.

Job description and application form from District Works Officer, King's Lynn Health District, St. James' Hospital, Exton's Road, King's Lynn.

THE DAVID LEWIS CENTRE FOR EPILEPSY
Warford, Alderley Edge, Cheshire SK9 7UD

APPOINTMENT OF ENGINEER

Applications are invited for a successor to the present Engineer who is to retire in mid-1978.

Applicants should hold HNC in Mechanical or Electrical Engineering or equivalent qualification with the appropriate certificate in the other discipline.

Salary scale £4,656 to £5,610, plus nationally agreed supplements and plus allowances for Fire and Safety responsibilities.

Please write to the Director for a job description and application form, which must be returned by 23rd March, 1978 to: Dr. R. H. E. Grant, Director, David Lewis Centre for Epilepsy, Warford, Alderley Edge, Cheshire SK9 7UD.

(All applications should be marked 'Private and Confidential').

Closing dates

Recruitment advertisers are requested to set closing dates no earlier than three weeks after publication date of the Journal.
Monthly publications do not receive preferential treatment by the Post Office and circulation lists in hospitals also delay receipt of the Journal by many potential applicants.

To place an advertisement in the next issue of **HOSPITAL ENGINEERING,** appearing on **April 7, 1978,** please contact: **EARLSPORT PUBLICATIONS,** 17 St. Swithin's Lane, London EC4, 01-623 2235/8, by **March 29,** latest.

Winchester and Central Hampshire Health District
Royal Hampshire County Hospital

Assistant Hospital Engineer

Due to promotion our District Works Department is looking for a mechanically biased Engineer (male or female) to be responsible to the Hospital Engineer for the day-to-day running of part of the engineering function within the Winchester and Central Hampshire Health District. You will be actively involved in all aspects of the maintenance field with particular emphasis on the mechanical services and the effective operation of planned Preventive Maintenance Schemes, close involvement with maintenance personnel on work in hand and ensurement of strict budgetary controls.
Applicants must be qualified to ONC (Electrical or Mechanical) or City and Guilds (full Technological standard).
Salary £3,522 pa, rising by annual increments to £3,988 pa (inclusive of pay enhancements), plus bonus payments.

Application forms and job description obtainable from District Personnel Department, Royal Hampshire County Hospital, Romsey Road, Winchester. Tel. Winchester 63535, ext 350.

SOMERSET AREA HEALTH AUTHORITY
East Somerset Health District

Hospital Engineer

(Over 24½ points)
required for
Yeovil District Hospital, Yeovil, Somerset

Salary scale: £3,615 - £4,140 plus £291 per annum non - enhanceable supplementary allowances, plus £183 per annum responsibility allowance. Bonus payments are also made.
The successful applicant will be responsible to the Sector Engineer for the management of the Engineering Section of the Works Department of this modern, acute hospital.
Applicants should have completed a recognised Apprenticeship and be in possession of an approved qualification, as detailed in PTB 261 (Electrical qualification preferred). A sound experience in all aspects of electrical and mechanical engineering is required, and the applicant should be able to demonstrate management and supervisory ability.

Application forms and further details can be obtained from: Mr. B. Silk, Administrator, Personnel Services, Yeovil District Hospital, Yeovil, Somerset. Closing date: 13th March, 1978.

CALORIFIERS +
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CALENGE LTD.
1 Victor Road
Bristol
BS3 3LW

The Royal Masonic Hospital
Ravenscourt Park,
London W6 0TN

CHIEF ENGINEER

To take charge of the Engineering, Electrical and Building departments of the largest private hospital in the United Kingdom. Suitable applicants should be experienced in all aspects of works management. Candidates should be qualified by HNC in Mechanical or Electrical Engineering with appropriate endorsements in accordance with Circular 261 of the Professional and Technical (B) Whitley Council for Health Services.
The Royal Masonic Hospital is undergoing a two-year modernisation programme. Also a Planned Preventive Maintenance Scheme is being implemented. Accommodation for married or single successful applicant can be made available at a reasonable charge.
Salary: £5,449 to £6,155 per annum inclusive.
For application form and job description apply to the Chief Executive Officer at above address, telephone number 01-748 4611. Closing date: 14 days from the date of this advertisement.

Solihull Area Health Authority

Hospital Engineer

Marston Green Hospital

A Hospital Engineer (male/female) is required at Marston Green Hospital to manage the engineering and building operational and maintenance services and associated staff. This is a senior appointment requiring considerable experience and management ability.
Applicants should have served a recognised apprenticeship and hold an HNC/HND in mechanical or electrical engineering with appropriate endorsements. Salary scale commencing at £3,854 rising to £4,474 pa inclusive of Phase 1 and 2 supplements, plus additional payment for excess hours up to 10% of salary. Residential accommodation is available at reasonable rental.
Application forms and job description available from the Area Personnel Officer, Solihull Area Health Authority, 83 Homer Road, Solihull, West Midlands.
Applications to be returned by: 17th March, 1978.

Index to Advertisers

HOSPITAL ENGINEERING

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for non-members of the Institute of Hospital Engineering wishing to subscribe to the Journal

Please send me one year's supply of Hospital Engineering commencing with the .... issue.

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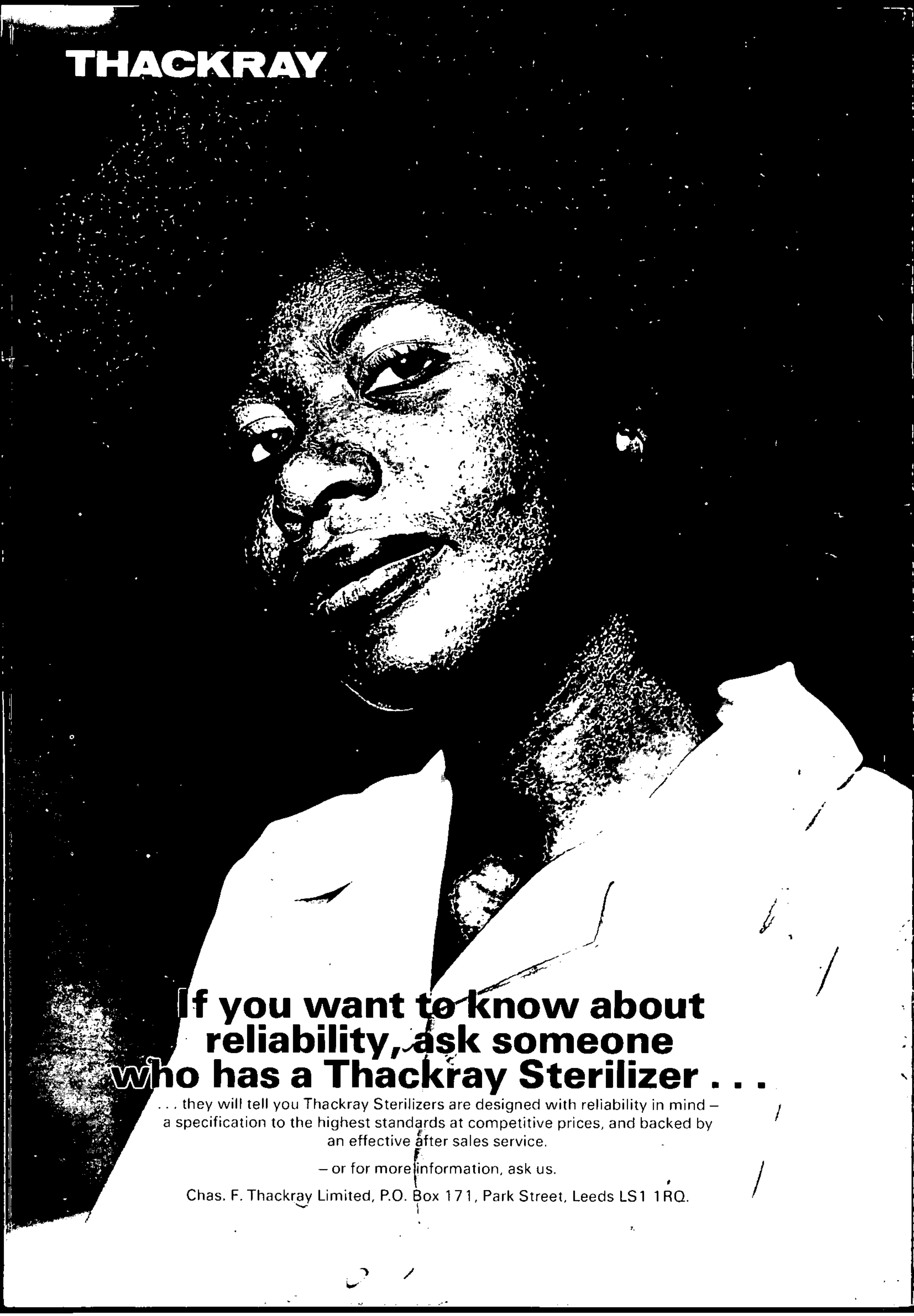
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