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The use of quantitative reliability techniques in the design of medical equipment

by B. SAYERS B.Sc., A.M.C.T., C.Eng., M.I.E.E.

This paper outlines the quantitative approach to reliability using a simple patient-alarm system as an illustrative example. The accuracy attainable in a predictive assessment is indicated and typical failure rates for components and equipment are given. Two methods of determining the reliability requirement of medical equipment are detailed and the paper concludes with a brief resumé of the work done by the Systems Reliability Service in the medical field.

Introduction

Medical equipment has to be highly reliable as a failure may cause the loss of a patient's life. The use of sample testing to determine reliability is expensive, time consuming and may result in an inaccurate answer because design developments have altered the equipment. Collection of field data implies a possible loss of patient's lives during the process and, as with sample testing, the answer comes too late. The use of quantitative reliability techniques enables accurate comparisons to be made between the reliabilities of equipments while still at the design stage and highlights the critical areas of a design so that improvements can be made before production is started.

Reliability

We all use the word reliability in our normal everyday life. However, the majority of people use the word subjectively—'very reliable brakes' '. . . is that sufficiently reliable', '. . . more reliable'. To the reliability analyst, such subjective judgment is insufficient. One man, driving a car only 5 000 miles in a year, might consider a breakdown every 5 000 miles indicates an adequately reliable car, whereas the commercial traveller covering ten times this distance in a year would consider the car totally unacceptable from the reliability point of view if he experienced ten breakdowns in a year. Hence the reliability analyst needs a quantitative definition of reliability, and such a definition is that:

> 'The reliability of an equipment is the probability of that equipment performing in the manner desired for a specified period of time under the relevant environmental conditions'.

The normal requirement of medical equipment depends upon the particular use to which that equipment is put. A lung ventilator, for example, may be required to operate continuously for long periods without attention, whereas an X-ray machine may only be called upon intermittently and for short periods. The reliability requirement is, however, that the equipment should perform its functions, on demand, at any time and that it should not perform these functions

Based on a paper presented to the 32nd Annual Conference of the IHE, Norwich, April 1976

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incorrectly. Put more simply, there should be no failures on demand and no incorrect operations due to equipment malfunction.

As we all know, it is rarely, if ever, possible to be completely confident that failures of equipment will never occur; however careful the design, however accurate the manufacture, random failures can and do occur. *The most that we can ever say is that there is* a low probability of a failure of one sort or another. What do we mean by probability and, more particularly, what do we mean by low probability? How can we quantify the term?

Probability

Consider the tossing of a coin. Most people would accept that, provided there is no bias in the coin, over a large number of trials there is a 50 : 50 chance of the coin falling either heads or tails. In mathematical terms, the probability of achieving heads, say, is 50/100 or, more conveniently written 5×10^{-1}. No one would argue that this is a low probability. Consider the probability of being killed by fire. Most people would think that there is a low probability of being killed by fire in this country and yet 800 people, on average are killed each year[1]. Assuming a population of about 60 million people, this means that the *chance of being killed by fire is about 1 in 100 000* or 10^{-5}. So we have quantified roughly what the average person thinks of as a 'low probability'.

It is instructive to construct a bar chart which shows the range of probabilities with which we are concerned in our normal everyday life. Such a chart is given in Fig. 1.

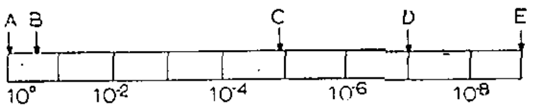


Fig. 1 Everyday probabilities
A Probability of an event which will definitely occur, e.g. death
B Probability of tossing heads with a coin
C Probability of dying in a fire
D Probability of being killed by lightning
E Probability of a meteorite 'hit' on a specified site

A majority of people would class events with probabilities of occurrence less than 10^{-5} from unlikely for a 10^{-6} probability down to highly improbable for a 10^{-9} probability. Hence the normal range of probabilities which appear meaningful to most people is from 10^{0} to 10^{-5}.

Design criterion

Returning to the reliability definition, we are now able to put a more precise meaning to this definition. We require a high reliability from our medical equipment and we know that high reliability is coupled with a low probability of failure. Perhaps we may consider that we shall be designing very well if we can achieve failure probabilities as low as 10^{-5}, but we feel intuitively that we should achieve better figures than 5×10^{-1}, i.e. the tossing-of-a-coin concept. What reliability requirement should be expected of our medical equipment?

There are two aspects of the problem to be considered, i.e., safety and availability. If a lung ventilator fails then a patient's life is in danger, whereas if an X-ray machine fails then the most likely consequence is that patients who are to be examined will have to wait for another appointment. The lung-ventilator failure is a safety problem, whereas the *X-ray machine failure is an availability problem.* For the purpose of this short paper, only the safety case will be considered since this is obviously the most important.

To determine the reliability requirement of medical equipment which has a high probability of causing death, in the event of failure, is extremely difficult. It is unrealistic to state that such equipment must never fail and, if we insist on too high a reliability requirement, the cost of the equipment will become excessive. On the other hand, too low a reliability requirement will mean an unacceptable mortality rate amongst users of the equipment. There are many approaches which help to determine what should be the reliability requirement. Two of these approaches are now outlined.

The 'boundary approach' considers other risks and seeks to relate the risk of using medical equipment to the other risks of life. A useful example is the risk of being accidentally killed in the home. There are slightly less than 10 000 accidental deaths in a year in the home, which gives an individual probability of such an event as about 10^{-4} per year. It is likely to be unacceptable if the probability of accidental death in a hospital is worse than that in the home so a boundary figure for accidental death in a hospital ought to be somewhat better than 10^{-4} per year. The risks involved in the use of a piece of medical equipment are only a small part of the total risk in hospital. Human failure on the part of medical staff, falls down stairways, electrocution, incorrect drugs or treatment etc., are some of the other contributors to total risk. If we estimate that equipment usage forms 10% of the total risk, say, then the probability of accidental death on such equipment ought to be about 10^{-5} per year. Hence, if we consider a lung ventilator, which may be in continuous use for a year, the probability of dangerous failure of that ventilator should not be worse than 10^{-5}.

The 'existing-risk approach' considers the present accidental death rate during medical treatment and states that the introduction of a piece of equipment should not worsen that death rate appreciably. For example, over the full range of surgical operations about 1 in 40 000 result in accidental death. The use of drugs results in an accidental death rate varying between 1 in 100 000 to 10 in 100 000, depending on the particular drug considered. These statistics approximate to a *10^{-4} probability of accidental death during* medical treatment. If we consider that medical equipment should be sufficiently reliable to limit accidental death during its use to 10% of the present figure, as derived above, then we are back to a 10^{-5} probability of dangerous failure of such equipment.

System assessment

Assuming that the design reliability requirement has been established how are we to assess whether our equipment meets this requirement?

In reliability work, individual probabilities of events can very often be expressed as functions of time. A common probability function of this type is that known as the exponential distribution which may be expressed by the following relationship:

$$P = 1 - e^{-Ft}$$

where t = time

F = failure rate of the equipment in faults per unit time

P = probabilty that the equipment will have failed by the time t when it was working at time zero

This formula can be expanded using the exponential series to show that when Ft is much less than unity, then

$$P \simeq Ft$$

In much of our reliability work, the exponential distribution can be assumed and hence if we know the equipment failure rate the probability of failure can be easily calculated for the period of time required. For a fuller treatment of this and other probability distributions References 7 and 8 are recommended. The system failure rate is derived from a knowledge of the individual failure rates of the various components of the system and, an illustrative example, is shown using the simple patient alarm call circuit of Fig. 2.

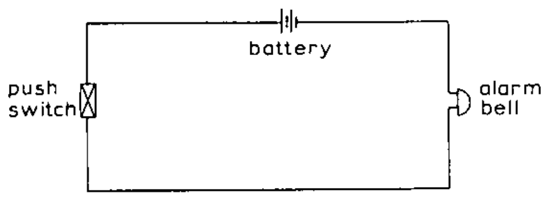


Fig. 2 Simple patient-alarm circuit

Such circuits are in common use for bed-fast patients who may be required to warn medical staff if an emergency situation arises, e.g. failure of a lung ventilator to which they are connected.

Failure rate figures for the components of this system have been obtained from the Systems Reliability Service Data Bank[10]—SYREL—and are shown in Table 1.

Table 1 Component failures in the alarm circuit

Component	Failure-rate data
Battery	1·0 fault per 10^6 h
Push switch	0·5 faults per 10^6 h
Alarm bell	2·5 faults per 10^6 h
Connections	0·3 faults per 10^6 h (1·8 faults per 10^6 hours total)

It is evident that failure of any one component or connection will cause failure of the overall circuit, and hence the system failure rate is the summation of the individual failure rates which is 5·80 faults per 10^6h. Assuming that the system is tested once a week (0·02 year), the maximum probability of system failure within that time interval is

$$P = Ft = 0{\cdot}06 \times 0{\cdot}02 = 1{\cdot}20 \times 10^{-3}$$

This predicted figure compares very closely with what is achieved in practice.

Where authenticated failure rate data on all components of a system is available, accurate information on system-failure probability can be derived therefrom. However, such data is often not available, particularly in the medical field where the collection of failure data is of minor importance when compared with the main effort of medical treatment. How then can the necessary information be obtained?

Equipment assessment

If the failure-rate data is not available from field experience, sample testing or prediction techniques are two alternative means of deriving the data. For highly reliable equipment, and we hope medical equipment falls into this category, sample testing can be both expensive and time consuming, since it may be necessary to operate large numbers of equipment for a long time to derive meaningful data on failures. For this reason, it is normally more satisfactory to resort to prediction to determine equipment failure rates. The prediction technique, which has been described more fully elsewhere[9], makes use of the fact that although equipment may be new or untried, the majority of its components will not. Consequently a great deal of information is available on component failure rates[10], some examples of which are given in Table 2. By considering the effects of each component failure and allocating the relevant failure rate for the component-fault mode considered, it is possible to summate the individual failure rates to find the 'dangerous', 'safe', and 'overall' fault rates of the equipment.

Table 2 Component failure rates

Component		Failure rate % per thousand hours
Bellows		0·5
Diaphragms	—metal	0·5
	—rubber	0·8
Gaskets		0·05
Springs	—heavily stressed	0·1
	—lightly stressed	0·02
Screws		0·05
Nuts, bolts, bars etc.		0·002
Resistors	—high stability carbon	0·05
	—wirewound	0·05
	—composition, grade 2	0·02
	—oxide film	0·01
Capacitors	—paper	0·1
	—synthetic film	0·05
	—ceramic	0·01
Transistors	—alloy germanium	0·1
	—alloy silicon	0·05
Relays	—PO type, general	0·2

It is of interest to look at the accuracy of this predictive method by comparison between predicted figures and actual field experience figures for a number of pieces of equipment.

Fig. 3 shows the relationships between predicted and observed failure rates in 45 different cases.

An analysis of Fig. 3 reveals that, on average, predictions are about 30% pessimistic and that the chance of being within a factor of two of the true failure rate is about 70%. 96% of the predictions lie within a factor of four. Such accuracy is adequate for the purpose of a system reliability assessment.

Finally, it is worthwhile to look at Fig. 4, which shows the spread of the failure rates of some component parts, equipment and systems from selected fields of experience. It is quite clear that as the reasonably reliable component parts are built into more complicated equipments the reliability reduces. When systems are constructed from this equipment, reliability suffers even more, unless adequate reliability techniques, such as the use of redundancy or self-monitoring circuits are, employed to counteract this tendency.

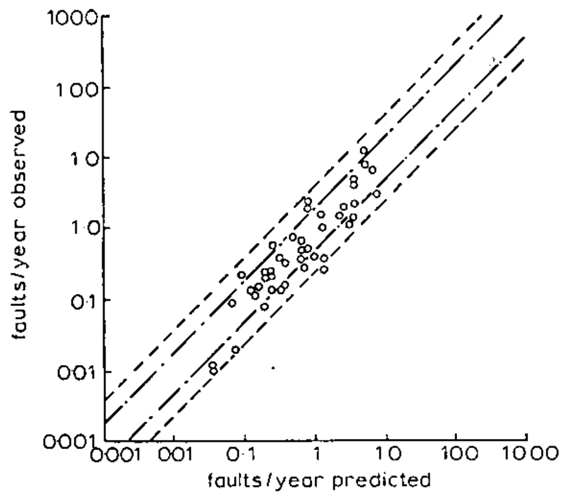


Fig. 3 Observed against predicted equipment failure rates for 45 cases

Present experience

Only a limited amount of work has been done so far in the reliability assessment of medical equipment, but what has been done indicates that there is a very real need for this work to be extended as rapidly as possible. Lung ventilators, for example, on which a patient may rely for a long period of time, are shown to have a relatively high dangerous failure rate. Even the best of these machines comes nowhere near the 10^{-5} probability of dangerous failure which it is thought is required. Very reliable monitoring facilities are therefore necessary for these machines, and our experience at present suggests that some of the commercially available units are not adequate to meet the requirements. For example, the best lung-ventilator monitor which we have looked at, from the reliability point of view, has a fail danger probability slightly worse than 10^{-3}, assuming complete weekly tests are carried

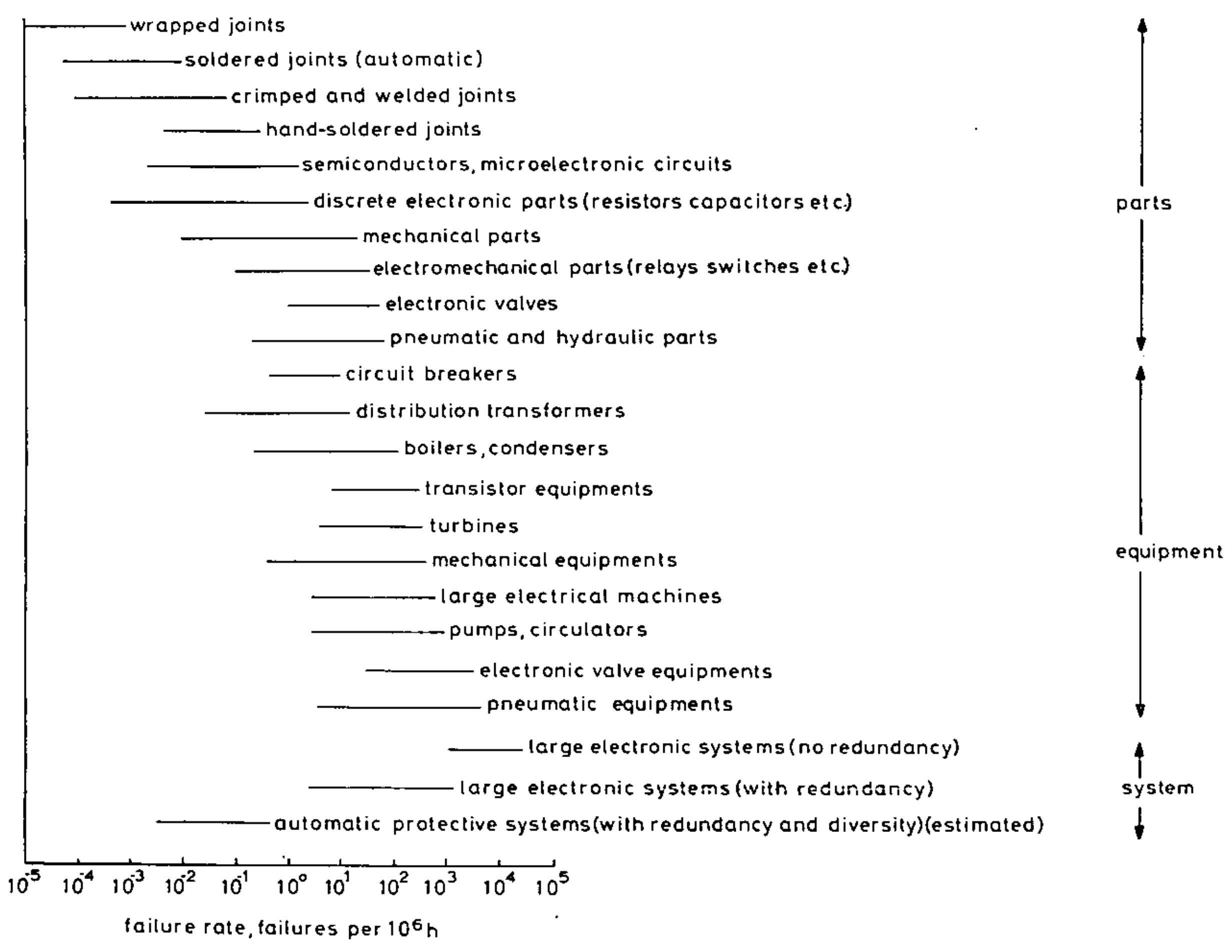


Fig. 4 Failure rates for parts, equipments and systems

out. To achieve an overall fail-danger probability better than 10^{-5} for the machine and monitor combination, the machine must have a fail-danger probability better than 10^{-2}, Such reliability is difficult to attain without recourse to redundancy and diversity techniques, which would inevitably result in an increase in price. In addition, no allowance is made in these calculations for human fallibility. It is assumed that if a lung ventilator fails and a monitoring system alarm operates, then the medical staff take the correct approach in dealing with the situation. If they do not, there is a third failure mode in the system—the human failure mode. When it is considered that the decisions have to be made and the actions taken within about 30 s, this failure mode may be most important. The Human Factors Data Bank indicates a fail-danger probability lying between 10^{-2} and 10^{-3} for a trained operator under such stressful circumstances.

Our work in the fields of haemodialysis and peritoneal dialysis lead us to similar conclusions to those for lung ventilators. The machines seem to be rather less reliable, but the patient situation is not so critical for a variety of reasons. Again, the difficulty is that of determining what is the required reliability.

Conclusions

There is a time honoured phrase which is true in many cases—'you get what you pay for'. If product quality is considered, the truth of this phrase is self-evident. If reliability is considered, then paying more is certainly no guarantee of a more reliable product. A safety pin is a cheap and reliable product. Alternative fastening devices are generally more expensive and usually less reliable.

If price is no guide line to reliability, and a highly reliable product is the aim, then how can the reliability be assessed in any other way than by a predictive technique. Sample testing is expensive and time consuming, and will produce an answer so late that developments will have rendered the equipment obsolete in the time. Field data on medical equipment implies failures in use, and therefore possible loss of life by patients under treatment. As with sample testing the answer is obtained too late. The predictive-assessment technique enables true comparisons to be obtained between various equipments even as early as the design stage. It gives valuable information on critical areas of reliability and enables a reasonably accurate figure for failure rate to be obtained before the equipment is put into use.

This paper has attempted to show how predictive-assessment techniques can be used for medical equipment and has given guide lines to the reliability which is required from such equipment. Use of these methods by designers and equipment operators can only be of benefit to the patients, who are the ones in the unfortunate position of having their lives at risk—and who knows—any one of us may be in that position one day!

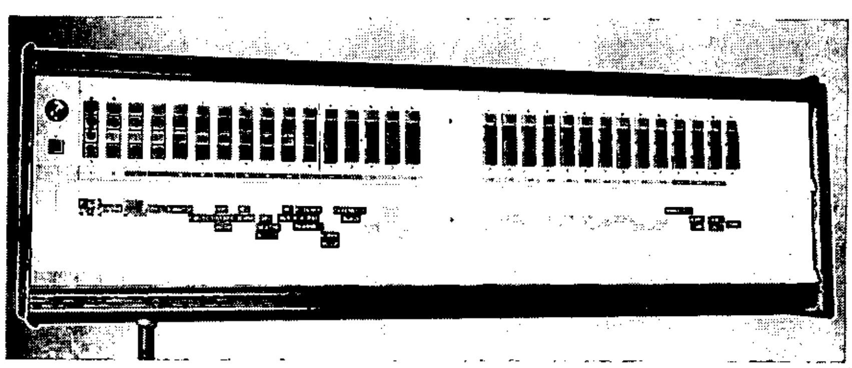
References

1 Annual abstract of statistics no. 103, HMSO
2 Sayers, B.: 'Assessing fire protection systems', UKAEA
3 Stewart, R. M.: 'High integrity protective systems on hazardous chemical plants', ICI Ltd., HOC Division
4 Hensley, G.: 'Plant and process reliability', UKAEA
5 Farmer, F. R.: 'Siting criteria, a new approach'. UKAEA. Presented at the IAEA Symposium on the Containment Siting of Nuclear Power Reactors, Vienna, April 1967
6 'The building regulations 1965', HMSO
7 Green, A. E., and Bourne, A. J.: 'Safety assessment with reference to automatic protective systems for nuclear reactors', UKAEA AHSB(S) R.117, 1966
8 Feller, W.: 'Probability theory and its applications'. John Wiley & Sons
9 Eames, A. R.: 'Reliability analysis of protective equipment', UKAEA. 'An introduction to reliability assessment.
10 Syrel Reliability Data Bank, UKAEA Risley

Interactive alarm system

A new interactive safety system introduced by Scarvale Ltd. is designed to be installed relatively easily in both new and existing buildings. Intrac, an electronic telemetry control surveillance and detection system, gives instant warning of a fire hazard and automatically alerts emergency services.

The system consists of a central control panel connected to outstations, which cover the various fire-risk zones. The conventional smoke detectors, heat detectors and break-glass call points in each zone are linked to an outstation, which automatically operates the fire alarms in that area in the event of a fire. A telemetry interrogation module continuously checks each outstation, relaying changes in condition to the central control panel where audible and visual signals indicate fires or faults in the system.



Any fire-detection signal received by the central control panel automatically initiates a flashing warning light on the panel to identify the area in which the fire is taking place. In addition, an audible alarm is sounded, the master fire alarm is operated and support services are alerted.

All points in the system are linked by two cables, which allow for easy installation and enable alterations, either in part of the building or in the safety system, to be carried out with remainder of the fire-alarm system still operative.

Energy conservation

by R. H. MORGAN, C.Eng., M.Inst.F., F.I.Hosp.E., M.I.H.V.E., M.I.Plant.E.

With energy costs rising rapidly, design and maintenance engineers need to reconsider their ideas on fuel conservation. This article suggests various methods of achieving fuel conservation together with the introduction of optimum controls for both heating and boiler installations.

There is at the present time a serious world shortage of energy. Coupled with this shortage is the extremely high premium required by the producing countries which presents a particularly embarrassing problem for this country and an expensive one for industry generally.

There are a number of precautions that individual engineers responsible for fuel-consuming appliances used in heating installations should take to ensure that fuels are conserved and used to the maximum advantage.

Intermittent heating

The technique of intermittent heating has been well known for a number of years, but its effectiveness has somewhat varied to a considerable extent, mainly because of a lack of suitable controls.

Mr. Morgan is a teacher with the Mid-Glamorgan Education Committee

The most common method of intermittent control system used today is the type that uses the compensation control, incorporated in an 'on/off' heating system. To explain the principles of such a system, a low-pressure hot-water radiator system has been selected, as this system is one of the slowest responding systems in wide use today. Fig. 1 shows the results from such a system based on an occupied period of 10 hours in 24, and a boiler boost capacity of 25% over and above design conditions; the building is a light structure with low thermal capacity.

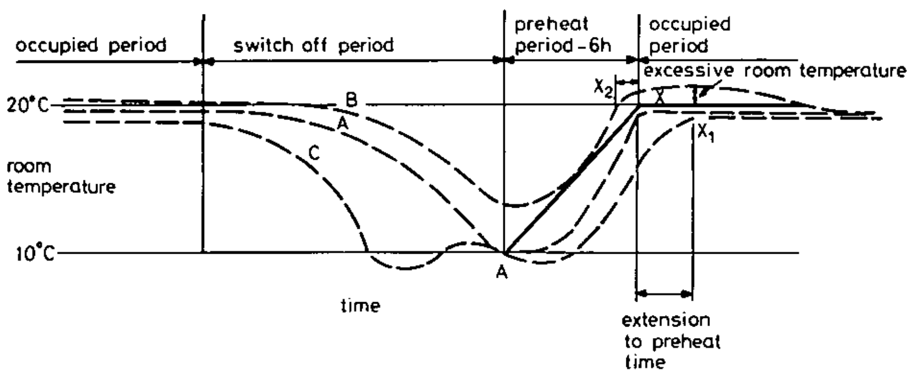


Fig. 1 Temperature against time for a low-pressure hot-water radiator system
A Ideal room temperatures
B Mild room-temperature decay
C Severe room-temperature decay

The line AX has been calculated to be a preheat period of 6 h, to raise the room temperature from 10°C to 20°C under ideal conditions, but in practice it is shown that, when a severe room-temperature decay is experienced, the room temperature reaches 10°C more rapidly, fluctuates around this bare line of 10°C by the use of frost thermostats or condensation protection, starting the preheat at A, resulting in an extended preheat period, and a delay in reaching the design temperature at X. Alternatively, with a mild room-temperature decay, the room temperature does not reach the base line of 10°C, so with the same preheat period, there is an excessive initial room temperature X, with a reduction in preheat time.

If the position of A can be varied automatically this would give an improvement. Such a controller has been developed recently, and is known as 'optimum start control', with tests to date showing considerable savings compared with conventional methods.

Basically the 'optimum start control' is an attempt to achieve the ideal conditions for starting and switching off intermittently used heating or air-conditioning systems. The controller measures internal and external temperatures. The room temperature then determines the work to be done and the external temperature will determine the time required (preheat period) to undertake this work. By then computing these values in the controller, an optimum start time can now be achieved automatically. A typical heating system with optimum start controls is shown in Fig. 2.

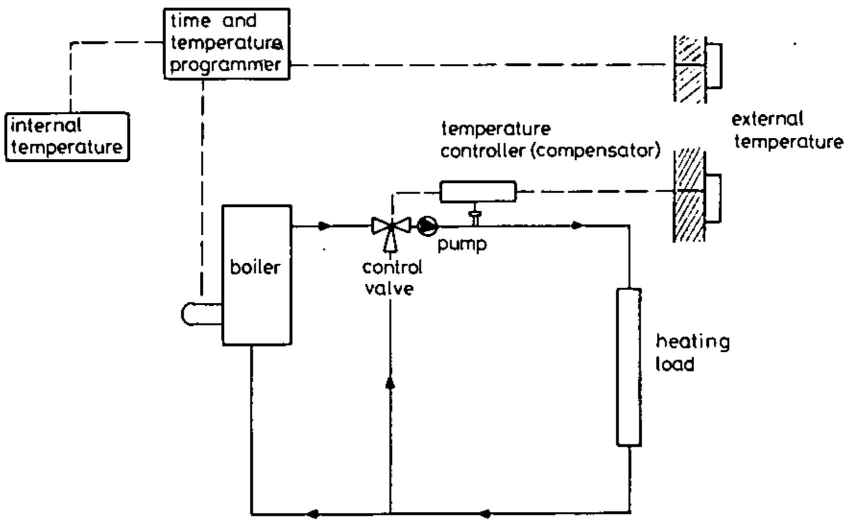


Fig. 2 Typical heating system with optimum start controlled

With the same conditions as in the compensator on/off controlled system the varying position of the preheat period start position can be shown.

Fig. 3 shows the trend in further decisions for varying levels of decay in room temperatures. The various decay-valued levels A, B and C start at the same 'off' time and values P and E show decays with later 'off' times. The values of D and E would be typical of extended operation of the plant owing to extended working periods. The line AX represents a locus of time/temperature start-diversion points, and these can be identified and used to form the basis of a single controller.

The severe-room-temperature line (*d*) illustrates the

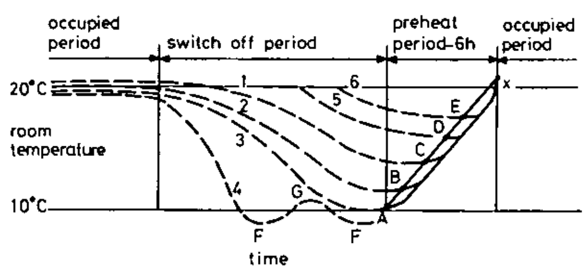


Fig. 3 Effect of varying levels of decay in room temperatures
- **a Milder decay**
- **b Mild decay**
- **c Normal decay**
- **d Severe decay**
- **e Varying shutoff point**

effect of room-temperature decay under severe conditions, when frost and/or condensation protection is used. As the temperature falls to point F, the plant will start up, to raise the temperature of the room through the proportional band of the controller. At point 'G' the heating will shut down, and, should the temperature decay again below 10°C, the operation will be repeated until point A is reached, when the plant will become operational under optimum start controls.

A development of optimum start controls is to include a load-sensing thermostat to replace the compensator control. The room thermostat must be located in a place of maximum demand for the zone or building being controlled. The application of this form of control is limited owing to the difficulty of selecting a suitable room to provide the control signal. Averaging arrangement of thermostats in this case would not be a satisfactory answer.

It is recommended that this system of control should be the basis for design of future intermittently controlled heating and air-conditioning equipment. It can also be introduced into existing systems quite easily; the uses that come to mind are: schools, offices, lecture rooms, staff residential accommodation, outpatient, orthopaedic and physiotherapy department, and even the air conditioning for operating theatres, where optimum-start controls can easily be introduced to new and existing plants. It is recommended that background heat is provided in operating theatres and ancillary rooms. This can be achieved by various methods, e.g. underfloor heating, heated ceilings, wall-mounted panels etc., but, irrespective of which method is used, optimum-start controls can be employed to ensure that the theatres are up to design conditions before operations commence at a specific time each day.

Before the installation of these controls can be considered one important question must be answered. When heavy fuel oil or coal is used as the source of heat, problems will occur when the plant is shut down and refired due to back end corrosion etc. To eliminate this, mixing- or diverting-value arrangements should be employed to enable the boiler or even calorifiers to work at normal design temperatures, i.e. the diverter

or mixing valve is used as the controlling mechanism. Tests carried out by the Department of the Environment have shown fuel savings of up to 42% can be made by developing the optimum-start controls. In practice it can be shown that a 25% saving over and above night setbacks, on/off, or similar controls can be achieved, and the capital expenditure can be recovered in a very short period. Most manufacturers have such controls on the market.

Combustion

All fuels contain carbon and hydrogen. Coal contains these elements along with oxygen in the form of a complex substance. Fuel oils consist of a homogeneous mixture of hydrocarbons of various types, together with small quantities of organic sulphur compounds and noncombustible materials. Gaseous fuels may contain hydrogen, hydrocarbons, with or without appreciable proportions of oxygen, carbon monoxide, nitrogen and carbon dioxide.

During the combustion process, carbon, hydrogen, hydrocarbons and carbon monoxide are burnt with air to form carbon dioxide, water vapour, and heat. The combustion technique is concerned with the development of the maximum quantity of heat from the fuel. It is then necessary to transfer the heat effectively to the water and reject the minimum practical quantity of heat from the appliance.

For maximum efficiency it is essential that the correct quantity of air is used. If too much air is used, fuel will be wasted, because additional heat will pass out of the system as sensible heat in the flue gases. If insufficient air is used, combustion will not be complete and the flue gases will carry away potential heat in the form of carbon and unburnt combustible gases, which should have been burnt in the combustion chamber. To ensure complete combustion, more air is required in excess of that required theoretically; the quantity of excess air required is dependent upon the fuel burnt. This excess air can be measured by the quantity of carbon dioxide or oxygen present in the flue gas. For the four main fuels the ranges of carbon dioxide percentages given in Table 1 represent practical operating conditions and every effort should be made to aim for the higher value in each case rather than settle for the lower value.

Table 1

Fuel type	Carbon dioxide in flue gas %
Oil	10–13
Solid fuel	10–14
Town gas	6–8
Natural gas	8–10

Fig. 4 indicates the relationship between carbon dioxide, boiler efficiency, and excess air values with a varying percentage of carbon dioxide using Seigurt's formula to determine the stack loss. The following assumptions are made:

Fuel used: fuel oil with $K = 0{\cdot}31$

Boiler flue-gas temperature = 246°C (constant)

Burner air-inlet temperature = 24°C (constant)

As previously mentioned, it can be shown from Fig. 4 that, to obtain the maximum boiler efficiency, approximately 13% of carbon dioxide should be present in the flue gas.

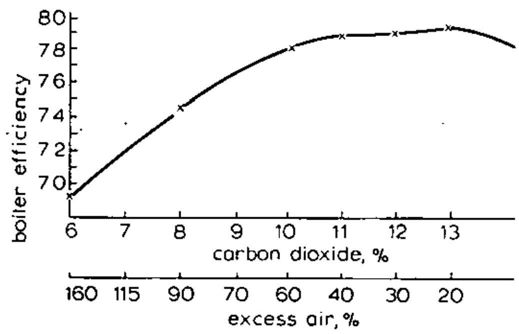


Fig. 4 Maximum boiler efficiency

Another important feature of complete combustion is the smoke emitted from the flue gases. This can be assessed on the Bacharach scales. This is a simple method of assessing the quantity of stack solids in a measured volume of flue gases. When oil plants are correctly operated, the Bacharach numbers should comply with Table 2.

Table 2

Grade of oil Redwood numbers	BS 2869 class	Bacharach number Target	made permissible
35	D	1	2
200	E	2	3
950	F	2	4
3500	G	2	4

In adverse cases, smoke emission from the stack may occur. The smoke indicates poor combustion and infringement of the Clean Air Acts 1956 and 1968 may result, under which it is an offence to permit the emission of dark smoke, i.e. stack two on the Ringelmann chart, for prolonged periods.

The function of the boiler is to transfer the heat generated by the combustion process through the heating surfaces to the water contained within the boiler. If these surfaces are covered by a layer of fireside deposits or scale on the water side, both of which are relatively poor conductors of heat, heat transfer will be restricted, which results in a loss of boiler efficiency. It is therefore essential to maintain both the gas and water side of a boiler in as clean a condition as possible. The first indication that a boiler is becoming fouled is reflected in an increase in the flue-gas temperature. A 17°C rise results in a loss of approximately one percentage point of efficiency. As a general guide, it is recommended that boiler gas-side surfaces are cleaned on a flue-gas temperature rise of 40°C for oil-fired, and 55°C for solid-fuel-fired boilers above the correct operating temperatures, in accordance with the boiler makers or commissioning data. It is important therefore that the boiler-outlet flue-gas temperature for a clean boiler is determined initially during commissioning tests. If commissioning test results are not available, the criteria will have to be established subsequently and immediately after boiler cleaning.

The firing rate of burner output should be checked periodically. If it is greater, the efficiency of the boiler will be reduced because of an excessive flue-gas temperature.

Boilers operate at optimum efficiency when the system load matches the boiler output under continuous firing. If the load is less the firing equipment will have to operate at variable firing rates, which can involve on/off, high/low/off, or modulating operation, according to the design of the equipment. Therefore, for maximum efficiency, the minimum number of burner on/off or high/low/off cycles, and stable operation of modulating burners are desirable. If necessary, higher operating efficiencies can be achieved by derating the burner output to the load requirements. Where multiboiler installations are used, maximum efficiencies can be achieved by operating one boiler at 100% instead of two boilers at 50% each.

Many boilers operate with a negative pressure on the gas side. If the boiler construction is not sound, air ingress will occur, which results in a reduction of boiler efficiency similar to that produced by excess air. The following areas of the boiler should be checked:

(*a*) smokebox doors
(*b*) burner-to-furnace seal
(*c*) intersection leakage on sectional boilers.

One method used for checking these areas is with a lighted taper.

Although there are many other factors governing the efficient running of boiler plants, the previous points have been discussed mainly to introduce another comparatively new idea, the results of which can be installed in existing plants as well as new boiler plants.

Most of today's continuous-process plants operate with a fair degree of efficiency, but certain variables continually exist, e.g., in a steam boiler plant, fuel calorific value, supply-air temperature, air pressure, air humidity, feed-water temperature, and boiler condition. In themselves, they are perhaps not so significant but an accumulation variations of these factors can contribute appreciably to the plant efficiency. Use of a digital computer to compensate for these changes can cost possibly more per year than is recouped from savings, so a relatively inexpensive optimiser control has been developed which is known as the Vertoak performance optimising control. This has been designed largely to provide optimum processing efficiency by acting as a trimming control for a plant's main process controllers.

Principally, the application needs to be a continuous automatic process where the prime function can be measured and analysed and thus controlled to a given set point by a primary control loop. The Vertoak control enables the control engineer to optimise the plant performance under varying demand conditions and to compensate for changes in conditions of both the controlled and uncontrolled variables.

It operates on direct analogue inputs, either electric or pneumatic, through suitable measuring instruments, and in principle is an analogue computer which performs an optimising function. Unlike a digital computer the Vertoak controller does not require a mathematical model or process simulator, but uses the process itself as the model, and learns and modifies its control responses according to actual process conditions. It does this by manipulating the secondary variables to maximise or minimise a prime performance parameter (the performance index) and is capable of correlating the effect of manipulating simultaneously four such secondary variables. It will then calculate the appropriate control responses for each, to optimise the plant performance. In addition, four other variables may also be fed into a constraint generator within the controller to ensure that during optimisation these inputs are maintained within their respective preset upper and lower limits.

When applied to a system for boiler control, the Vertoak controller operates by continuously monitoring the thermal efficiency of the boiler, applying small variations to the fuel/air ratio alternately, either side of the set point of the combustion regulator, and comparing the results obtained with the previous efficiency readings. In effect, the optimiser superimposes a low-amplitude hunting characteristic onto the fuel/air ratio setting, which itself will vary according to the signals from the steam-pressure controller.

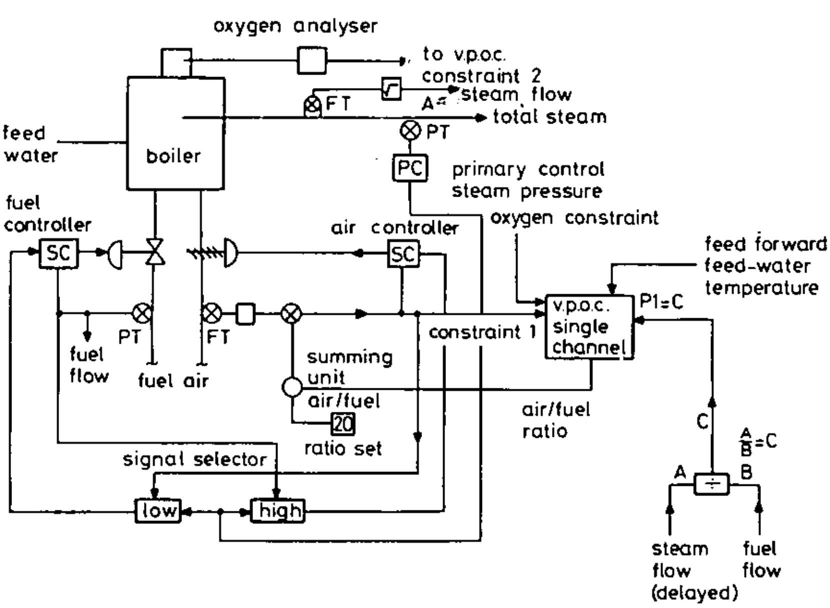


Fig. 5 Schematic of a v.p.o.c. system

A schematic of such an installation is shown in Fig. 5. Although shown with a 1-boiler installation, the controller can easily be incorporated into a multi-boiler installation or even furnace combustion control, pumping stations, platforming or reforming processes etc.

Steam pressure forms the prime variable and steam flow divided by fuel flow gives the measure of efficiency, the performance index. By use of this index, the controller is able to optimise the system while subjected to fluctuations in steam demand. The fuel/air ratio is selected as the secondary variable to be manipulated and, since the ratio should not exceed certain safe operating values, the values are recognised and set up in the constraint generator. Similarly the oxygen or carbon-dioxide analyser of the flue gas is chosen as the source of an addition constraint, as the results of incorrect combustion have been explained previously.

The system is relatively simple to set up and economies can be realised immediately by the optimisation of fuel consumption and the minimisation of pollution. Fuel savings of approximately 5% can be gained by the use of the controller. Additional benefit can be obtained by the application of a feedwater-temperature forward signal to the steam-pressure controller, since this will precondition the system to fluctuations in feedwater temperature. When deciding to introduce or design a system incorporating the Vertoak controller, consideration must be given to the size of the plant so as to compare the expenditure, with potential savings in fuel and better pollution control. Obviously, this figure will vary with the type and cost of the fuel used.

Conclusion

Previous Sections have highlighted the main features regarding plant efficiencies with the introduction of optimising controls in existing plant, together with the possibility of designing new plant with the inclusion of such controls. Although there are many new products on the market they need not necessarily use new technology, but because of the sudden increase in the price of energy, one has now to look at these products and ideas in the new set of circumstances.

Acknowledgement

The author would like to thank K. G. Hanlon for his co-operation and assistance in preparing this article.

INTERNATIONAL HOSPITAL EQUIPMENT & HEALTH SERVICES EXHIBITION

NATIONAL EXHIBITION CENTRE BIRMINGHAM
14-17 JUNE 1976

The International Hospital Equipment & Health Services Exhibition is being held at the National Exhibition Centre, Birmingham, from the 14th to 17th June. This is the UK's premier event in the field of hospital and health-service administration, and it aims to give supplies officers, hospital administrators, domestic superintendents, laundry managers, engineers and others a chance to study the latest equipment, materials and techniques available.

Associated with the exhibition is a conference, to be held from the 15th to 17th June, in the Metropole Hotel in the grounds of the NEC. Among the topics to be discussed will be the changing shape of the health service and the effects of the white paper on public expenditure and the consultative documents on priorities in the health services. All three days of the conference should be of interest to administrators in the health service, but tickets are also available for one or two days only.

The programme is as follows:

Morning Day 1: **The changing shape of the National Health Service.**

Chairman: Dr J Barber, Editor, *Health & Social Service Journal*

'Zero Growth—a Regional view. What zero growth means in practical terms; and how it affects the 5-year plan'. Speaker to be announced.

'The hospital of the 1980s. Current medical techniques are being re-examined. How will the hospital service change?' Speaker to be announced.

Visit to Exhibition and luncheon

Afternoon: **The support services in the 1980s.**

Chairman: T. E. Nodder, Under-Secretary for Support Services.

'How will hotel services be provided in the 1980s?' 'How will changing technology affect catering, cleaning etc.?' *Speaker:* John Rice, Regional Catering Adviser, Wessex Region.

'The alternative methods. What are the advantages and economics of subcontracting?' *Speaker:* W. J. McLaughlan, managing director, Crothall and Company.

'The intermediate technology. Can appreciable savings be made by accepting only slightly less sophisticated hospital equipment? Design considerations, durability, obsolescence. The equipment for the job in hand.' *Speaker:* D. Brennan, managing director, Ellison Hospital Equipment Ltd.

'The impact of prospective changes on employment and training patterns'. *Speaker:* Alan Fisher, general secretary, National Union of Public Employees.

Morning Day 2: **The Health and Safety at Work Act.**

'How does the act affect hospitals? Who are covered, patients, staff, visitors? What, for example, must be done

NATIONAL EXHIBITION CENTRE BIRMINGHAM 14-17 JUNE 1976

about fire drills? Who is legally responsible under the Act?' *Speaker:* Martin Jukes, Q.C., Deputy Chairman, Health & Safety Executive.

'Methods of fire prevention and particular problems of patient handling in case of fire'. *Speaker:* R. D. Gajjar, Architect, Department of Health & Social Services.

Afternoon: **Infestation.**

'The basic problem. What creatures infest, their habits, and the effect of the presence'. *Speaker:* Dr. J. A. Freeman, Deputy Director, Pest Infestation Control Laboratory, Slough.

'Design aspects for new and existing buildings to minimise infestation. Cost effectiveness of adapting existing buildings. The priorities'. Speaker to be announced.

'Maintenance problems associated with older buildings from an infestation point of view. The monitoring role of the building supervisor and district domestic services manager'. Speaker to be announced.

'Cost of infestation and cost of protection services'. Speaker to be announced.

Morning Day 3: **Water and effluent treatment.**

Chairman: Eric Hill, Chairman European Cleaning and Maintenance Association and Clerk, Guild of Cleaners.

'The cost of incoming water treatment and consequential saving in laundering costs. Heat recovery from processed water'. *Speaker:* R. J. Turner, Houseman Hegro.

'The latest regulations on control of quality of effluent discharged into drainage system. Responsibility for monitoring and control. The treatment of effluent containing "disposable" material'. Speaker to be announced.

Visit to Exhibition and luncheon.

Afternoon: **Clothing for long-term patients.**

'The importance of individual clothing in the prevention of institutionalisation of long-stay patients. Clothing for disabled people.' *Speaker:* Mrs. Marjorie Thornton, C.B.E., clothing advisor, Disabled Living Foundation.

'Laundry services to patients in the community. *Speaker:* Dr. Muir Grey, Community Physician, Oxfordshire Area Health Authority.

The conference and exhibition are sponsored by the *Health & Social Service Journal* and organised, on the sponsor's behalf, by Fairs Exhibition Ltd. of Haywards Heath, Sussex.

EXHIBITION

List of exhibitors

The following companies will be at the exhibition on the stands shown:

Arjo UK	98
Armitage Shanks Sales Ltd.	30
David Baker & Sons (M/Cr) Ltd.	64
Banks & Davis Ltd.	19
John Betts & Sons Ltd.	115
Biddle Engineering Co.	126
Clares Carlton Ltd.	15
COSHE	70
The Crompton Manufacturing Co. Ltd.	58
The Department of the Environment	24
Diversey Ltd.	88
Dudson Brothers Ltd.	80a
Dunlop Ltd. Precision Rubbers Division	14
Dyno-Rod Ltd.	66
EDANA	112
The Electricity Council	29
EMI Medical Ltd.	42
Ercol Furniture Ltd.	26
Euroclean Ltd.	3
Firth Carpets Ltd.	23
William Greeman & Co. Ltd.	5
Godfrey-Syrett Ltd.	87
Green Brothers (Geebro) Ltd.	61
Haigh (Hygiene) Ltd.	65
Harwell Research Centre	49
Health & Social Service Journal	31
Hendon Precision Engineering Co. Ltd.	107
Hille International Ltd.	90
Homa Castors Ltd	34
Home Counties Cleaning (Group Services)Ltd.	95
Hospital Metalcraft Ltd.	103
Independent Medical Systems	16

Lamson Engineering's document conveyor

Booth & Evans Gym Mats	1
Brittains Hospital Supplies Ltd.	32
Cape Engineering Co. Ltd.	59
B. Cartwright & Son Ltd.	116
Celairic Ltd.	23
W. W. Chamberlain & Sons Ltd.	113
Institution Supplies Leeds	83
Jaffa-Lux Ltd.	124
B. & J. M. Jungeling Ltd.	43
Keiper	78
Kerry Ultrasonics Ltd.	122
Kex Industrial Services Ltd.	39
L. V. Purchasing Co. Ltd.	48

NATIONAL EXHIBITION CENTRE BIRMINGHAM
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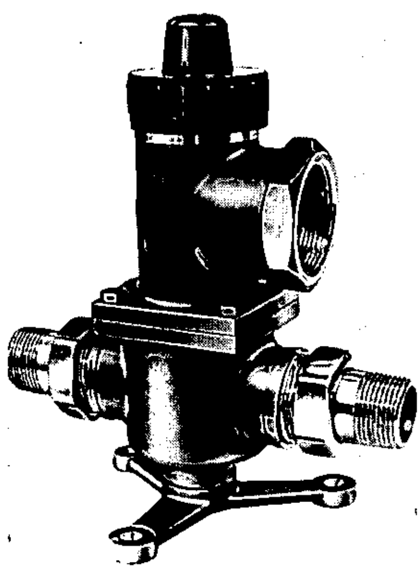
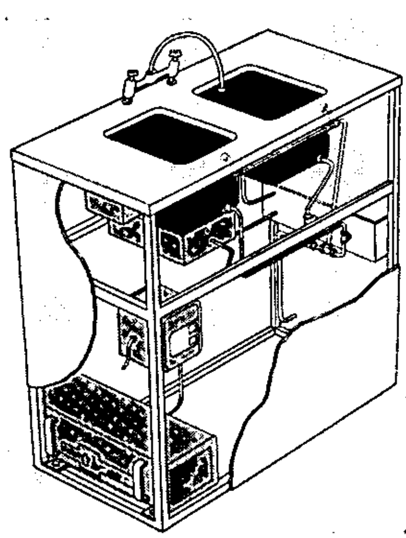
Lamson Engineering Co. Ltd.	36
Light Alloy Ltd.	97
Lonsto (International) Ltd.	111
Lyons Tetley Ltd.	89
M & M Electric Vehicles (Atherstone) Ltd.	72
Marker Board Supplies Ltd.	8
Mecanaids Ltd.	117
Medic-Bath Ltd.	100
Meynell Valves Ltd.	118
Milford-Astor Ltd.	119
Ministry of Defence	44
Morpeth Contracts Ltd.	113a
NCR Ltd.	77
Nelson Tansley Ltd.	60
Nilfisk Ltd.	109
Northwood Publications Ltd.	55
Nusonics Ltd.	69
Parker Knoll Ltd.	45
Permapure (Commercial) Ltd.	85
Plessey Communications Systems	125
Plushpile Carpet Co.	4
J. T. Posey Company	114
Primrose Plastic Products	7
Reed Medway Sacks Ltd.	6
Refuse Sacks & Holders Ltd.	99
Remploy Ltd.	41
Walter Sarstedt (UK) Ltd.	101
G. K. Scientific	10
SSI Fix Equipment Ltd.	38
Scotts Electrical	92
Shernfold Precision Compaktors	13
Simpla Plastics Ltd.	17
J. S. Smith (High Wycombe)	79
The Spastics Society	96
C. A. W. Stanbridge Ltd.	82
Static Switching Ltd.	91
Sterilin Ltd.	11
Stevenson & Son	9
Swifts of Exmouth Ltd.	37
Synrein Plastics Ltd.	110
Temp-Rite International Inc.	86
Tootal Workwear Fabrics	106
Twyfords Ltd.	94
Vetrella (UK) Ltd.	93
Vitopan Ltd.	46
Western Medical Ltd.	120
Wilkinson, Riddell & Larkins Ltd.	123
Wilmat Handling Co. Ltd.	121
Wittenborg Automat Ltd.	40
A. Yeates & Sons Ltd.	2





A new d.g.h. every year?

The British Gas School of Fuel Management has halved the cost of its fuel-managers and energy conservation officers course from £150 to £75 + v.a.t. for a 3-month period finishing in early July.

Mr. Peter King, head of the school, said in a speech earlier this year that Britain could have a new district general hospital every year for nothing: all the hospital service has to do is cut its energy consumption by 10%. 'During the fuel crisis two years ago', said Mr. King, 'there were hospital regions who effected fuel savings of 30% without unduly affecting hospital efficiency. If this figure could have been maintained we could have three new district hospitals a year. But the same regions were back to within 2% of their old figure a year after the immediate crisis ended'.

The school itself was set up by British Gas in support of the 'Save It' campaign and has already achieved an enviable reputation, the school, and the research station in whose grounds it stands, have helped many concerns to achieve quite dramatic savings in energy and has attracted many students from abroad, and even from some oil companies.

The course includes sessions on the following subjects: the world energy situation; the gas situation; financial implications; the fuel audit and fuel saving in practice; efficient operation of combustion systems; applications of instrumentation and controls; low-pressure hot-water systems; efficient boiler-plant operation; application of modelling to energy conservation; alternative methods of firing low-temperature plant; waste-heat recovery and recuperative burners; gas-fuel engines and the latest techniques in energy conservation. All lectures are supported by practical sessions. The course lasts five days and application forms are available from Mrs. G. Graham, British Gas School of Fuel Management, Wharf Lane, Solihull, West Midlands B91 2JW.

Order for medical gases

An order worth more than £100 000 has been won by BOC Ltd's Installation Engineering Department from the Wessex Regional Health Authority. The order is for the supply of piped medical gases to the new maternity unit at Southampton General Hospital.

The maternity unit will be the biggest in the UK and one of the largest in Europe. It will have more than 200 beds, 50 special baby-care units, 33 centralised delivery suites and two operating theatres.

BOC is installing two separate Entonox (analgesic) systems as well as oxygen, nitrous oxide, compressed air and vacuum piped distribution systems.

Institute news

1976 ANNUAL CONFERENCE

(left to right) Mr. John Bolton; the Lord Mayor of Norwich; Prof. D. C. Simpson; Mr. F. H. Howorth, Mrs. Howorth; Mr. Gwilym Morgan

A good time was had by all at the Institute's 32nd Annual Conference, held in Norwich from the 28th–30th April.

On the social side, delegates and their ladies were guests at a civic reception given in the city hall on the first evening. On the evening of the 29th a goodly company, filling the conference hotel to the point of overflowing, enjoyed the conference dinner dance to the full. Principal guests included the Lord Mayor of Norwich, councillor Mrs. Joyce Morgan and Mr. Gwilym Morgan, Prof. David C. Simpson, Immediate Past President, the Biological Engineering Society, and the Chief Engineer, DHSS, Mr. John Bolton and Mrs. Bolton. The company also included three Past Presidents of the Institute and their ladies.

(left to right) Mr. Gwilym Morgan; the Lord Mayor of Norwich, Councillor Joyce Morgan; Mr. F. H. Howorth, the President of the Institute; Mrs. Howorth

On the technical side, the conference programme included papers on 'The use of reliability techniques in the design of medical engineering equipment', 'Health and Safety at Work Act', 'Economics in Design and Operation of Hospital Engineering services' (given by four speakers from DHSS) and 'The consulting engineering abroad', thus embracing the wide spectrum of subjects which Council strives to include in conference programmes.

A separate programme was arranged for the ladies accompanying delegates and this too was much enjoyed.

Thanks are due in particular to the East Anglian Branch of the Institute, for the part its members played in ensuring the smooth running of all the proceedings.

Now we look forward to the 33rd Annual Conference, which is to be held in Pitlochry, Scotland, from the 27th–29th April 1977.

BRANCH OFFICERS

The following branch officers have been elected:

NORTH-EAST BRANCH

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Vice Chairman	W. W. Murray
Honorary Secretary	J. R. Gilderoy, 21 Denewell Avenue, Low Fell, Gateshead, Tyne & Wear, NE9 5HD
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Chairman	A. Peters
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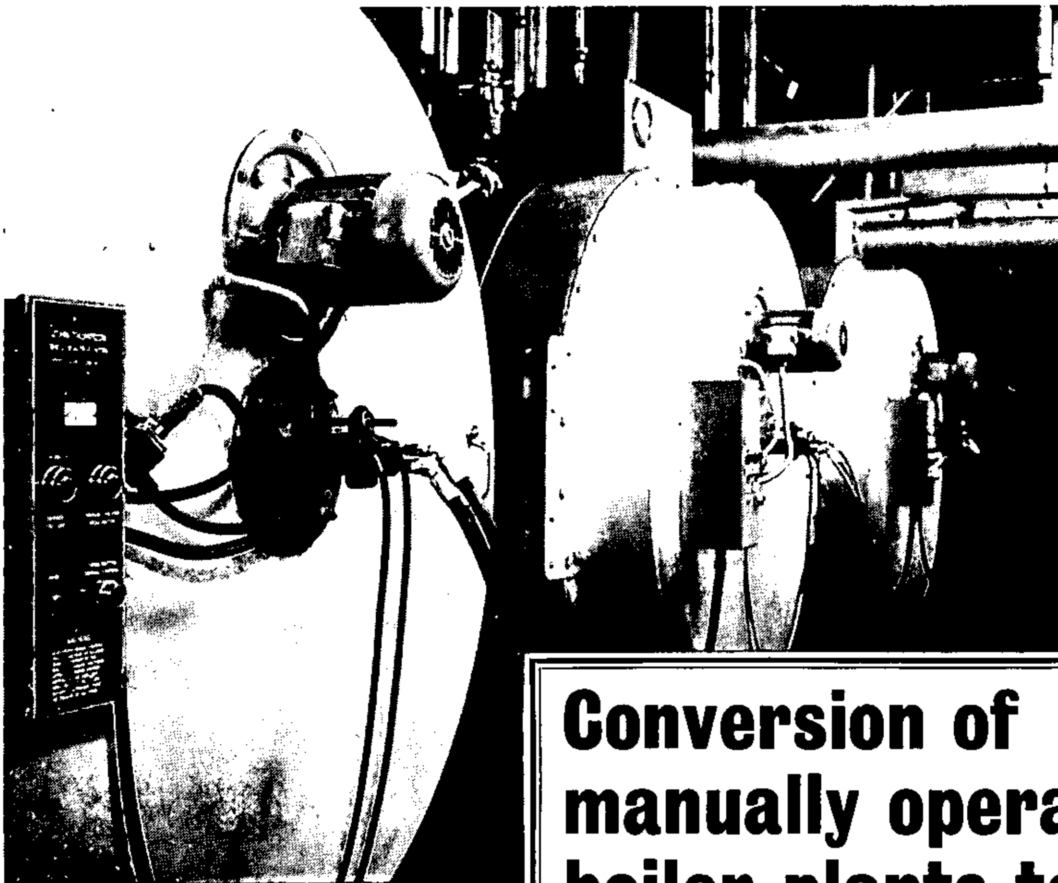

Conversion of manually operated boiler plants to automatic operation

by R. B. SIBLEY

The article reports on the economies arising from converting three manually operated steam-raising boiler plants at hospitals to unmanned, fully automatic operation by ascertaining the total running cost before conversion, cost of conversion and comparable cost thereafter, with a view to making recommendations for further conversion to automatic operation.

Introduction

During 1972 and 1973, the West Dorset Health Care District (and predecessors) converted three manually operated steam-raising plants at three hospitals to unmanned fully automatic operation.

The converted plants have now been in use for long enough to allow a careful comparison of the operating costs prior to and after conversion to form a basis for making recommendations on further changes at other establishments.

The stages to be reviewed are:

(*a*) details of the three steam-raising plants, the staff and their duties.

(*b*) details of the conversions carried out at the three plants and cost

(*c*) running cost before conversion compared with running cost after conversion.

Preconversion arrangements

The three steam-raising plants concerned are situated in completely different hospital complexes and had contrasting features as follows:

Plant 1—Damers Geriatric Hospital

Very old building with 56 beds spread over two floors, steam services include domestic hot water, central heating and small kitchen.

The plant consisted of two prewar *Harley Sugden* vertical 2-pass smoke-tube boilers, manually coal fired with a capacity of 340 kg/hr. fired alternatively at a working pressure of 2·5 bars.

Mr. Sibley is a hospital engineer with the West Dorset Health District, District Administrative Offices, Herrison Hospital, Dorchester, Dorset


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Plant 2—Dorset County General Hospital

Very old building with 64 beds spread over two floors, plus an attic and various other units situated in a selection of adjacent buildings offering a further 146 beds.

Steam services include domestic hot water, central heating, sterilising equipment, air-conditioning plant and a kitchen serving approximately 300 meals each sitting. In its preconversion state, the plant comprised three modern *Thompson Thermo-Pack* horizontal 3-pass smoke-tube boilers fired by *Brockhouse* variable-flame burner units consuming 950 seconds medium fuel oil, with capacities of 1814 kg/hr, 1814 kg/hr and 2267 kg/hr, respectively, at a working pressure of 6·5 bars

Normally, only two boilers are in use at any one time.

Plant 3—Portwey Maternity Hospital

Once again, a very old building with 68 beds spread over three floors. Steam services include domestic hot water, central heating and a kitchen serving 100 meals each sitting.

Adjoining the boiler house is a group laundry handling 20 000 articles per week, which consumes about half the steam-raising plant's total output.

In its original form, the plant consisted of three *Cochran* vertical-smoke-tube boilers fired by *Urquhart* low-flame/high-flame-type steam atomised burners using 95 seconds medium fuel oil with capacities of 794 kg/hr, 1020 kg/hr and 1133 kg/hr fired in pairs to capacity at a working pressure of 6·5 bars.

Preconversion labour requirements

The common factor of the three plants was the need for a continuous watch over the whole 24-hour period, and this required at least four watchkeepers for each installation.

The watchkeepers were graded as 'Boilermen' with terms of employment requiring them to devote their full time to boiler-house duties and no others. Indeed, insurance regulations required them never to stray outside audible range of the safety-alarm systems.

In general, a boilerman's duties consisted of day-to-day running of the steam-raising plant and associated equipment, maintaining an efficient and tidy unit, testing safety alarms and controls, blow-down boilers and gauge glasses, testing boiler water and adding treatment chemicals, and keeping an effective log of fuel, water and steam consumption.

PARTICULARS OF CONVERSION

Plant 1— Damers Geriatric Hospital

As a steady supply of steam had to be maintained, only one of the two boilers could be taken out of service at a time for conversion. The work was undertaken by Brockhouse Heating Co. Ltd., and conversion commenced in December 1972 proceeding as follows:

Installation of fuel supply

As this was previously a coal-fired plant, the initial work was the construction of a concrete base, piers to support the two 4 500 l fuel-oil tanks, and a bund (compound) capable of containing the contents of the fuel-oil tanks in the event of a rupture. Two fuel gauges and isolating valves to control the flow were fitted. A 25 mm fuel-supply line was laid a distance of 40 m to the boiler house, terminating adjacent to the boilers with a filter-assembly fuel gauge and isolating valves. A dead-weight fire valve was fitted in the line, controlled by fusible links suspended above each of the two burner units.

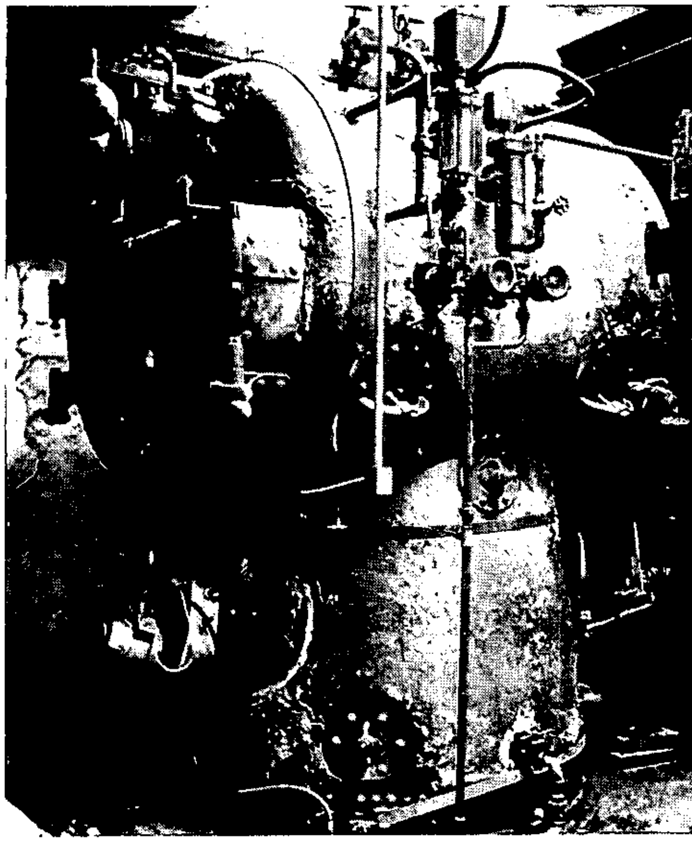


Fig. 1 Boiler at Damers Hospital

Burner units

The standby boiler was isolated and the coal door and grate removed. A new furnace was constructed from best-quality fire bricks and a new front plate was made to accommodate the *Brockhouse Pressure Jet Type 2NFL* burner unit.

The burner was fitted with a boiler pressure switch and a modulating pressure switch with Landis & Gyr photocell controls to comply with the Associated Offices Technical Committee (AOTC) recommendations. Grade of oil; 35 seconds, Redwood no.1.

Boiler feed pumps

The *Weir* steam-reciprocating boiler feed pump was removed and a *Worthington Simpson Monobloc type TM* electric feed pump fitted, complete with isolating valves, safety valve and *V Regg* nonreturn valve.

Controls

Flanges and pipe work were constructed to accommodate: one *Mobrey* dual control with sequencing blow-down valve; one *Mobrey* single control with sequencing blow-down valve, each fitted with isolating valves and drains.

Electrical
A new 400/440 V 3-phase 50 Hz supply was run from the mains room for the boiler-house central panel (approximately 20 m).

The new wiring from the control panel to the oil burner unit controls and feed pump was installed in p.v.c. cable and galvanised conduit, all to Institution of Electrical Engineers regulations.

Fig. 2 Burner unit at Damers Hospital

Commissioning
On completion the standby boiler was commissioned and placed online. The second boiler was then converted in exactly the same manner

Cost	£
Cost of conversion	2 610
Installation of alarm to the nearest permanently manned nursing station as required by AOTC	40
	2 650

Plant 2—Dorset County General Hospital

Preliminary work
The existing fuel-oil tanks were found to be unsuitable for the new lighter 35 seconds fuel oil. A temporary small fuel-oil tank was installed next to the boiler house and arrangements made with the fuel-oil suppliers to top up the tank daily. The existing tanks were removed and replaced with new tanks, giving a bunkering capacity of 90 000 l.

A new 50 mm supply line was constructed from the new tanks incorporating fuel gauges, isolating valves, fuel filters and a fire valve connected to the existing fusible links, positioned above each of the three burners. The new supply terminated adjacent to each of the three existing boilers in a 25 mm pipe. The cost of the new tank installation was £2 500.

Boiler conversion
The three *Thompson Thermo Pack* boilers were already fitted with *Mobrey* feedwater controls and alarm systems. The three *Brockhouse* fuel oil pumps and variable-flame burner units needed only minor modifications to burn the new 35 seconds fuel oil. The boilers were converted one at a time leaving two boilers to cope with the steady steam load.

Cost	£
Conversion work	278
Connection of safety alarm to the hospital telephone exchange as required by AOTC	50
	328

Plant 3—Portwey Maternity Hospital

The conversion at Portwey Hospital proved to be the most demanding. The work started during the latter half of the heating season, in 1973. Two of the three boilers had to be in service at all times, especially during the working day when the group laundry was in use. Therefore, the standby boiler was first converted and then put into service. This meant, for a period, two types of fuel oil were in use.

The following quotation was accepted and the work progressed as follows:

Fuel supply
(i) One of the two 18 000 l main fuel tanks was isolated, the steam-heating battery (necessary with the original 950 seconds fuel oil) was removed, the tank was thoroughly cleaned out and the fuel-oil gauge recalibrated, i.e. 0·835 specific gravity as compared with 0·95 specific gravity.
(ii) A 50 mm main fuel-supply line was constructed from the fuel tank to the boiler house (approximately 50 m in existing ductwork), terminating adjacent to each of the three boilers in a 25 mm pipe with filter assembly, fuel gauge and isolating valve. A dead-weight fire valve, controlled by fusible links suspended above each burner unit, was fitted to the main fuel-supply line.
(iii) One of the two *Weir* steam-reciprocating boiler feed pumps was removed to provide a base to site the three new *Worthington Simpson Electric* 2-stage vertex boiler feed pumps.

Installation
(*a*) *Front plates:* The existing oil burners were dismantled and the existing front plates modified to accommodate new oil-burner blast tubes. Front-plate refractories were made good with best-quality fire brick and solid insulation brick to existing combustion chambers. New burners and

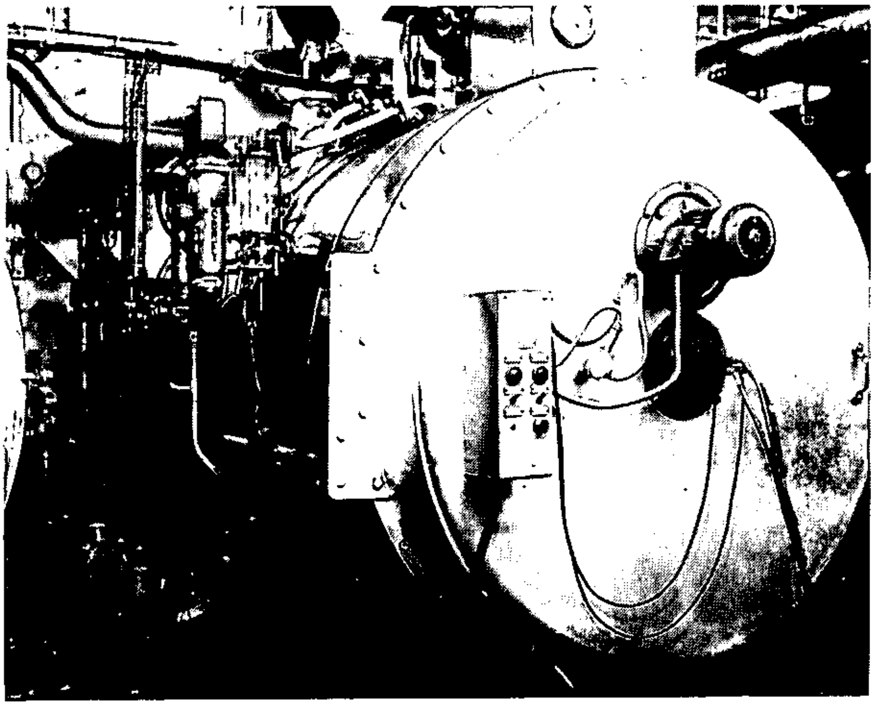


Fig. 3 Plant at Dorset County General Hospital

Landis & Gyr photocell controls were fitted to comply with AOTC. Each burner was equipped with one boiler pressure switch and one modulating pressure switch. Grade of oil; 35 seconds, Redwood no. 1. Electricity supply 400/440 V 50Hz.

Boiler feed pumps: Three *Worthington Simpson type TTM* 2-stage vortex boiler feed pumps were fitted, all were isolated on suction and delivery with handwheel valves, each pump being fitted with pressure-relief valves. A new condense supply line was installed from the condense receiver to each boiler feed pump. Each boiler feed pipe was fitted with one new *V-Regg* nonreturn valve.

Controls: Each boiler was fitted with one *Mobrey* dual control and one *Mobrey* single-control, each fitted with isolating valves and drains.

Electrical

All wiring from boiler-room distribution board to oil burners and controls was installed in p.v.c. cables and galvanised conduit, all to the Institution of Electrical Engineers regulations.

Commissioning

On completion of the installation the plant was commissioned and tested and left working satisfactorily.

Cost	£
Cost of the above	4 994
Additional for fuel tank cleaning	150
Installation of alarm to telephone switchboard as required by AOTC	50
Total cost	5 194

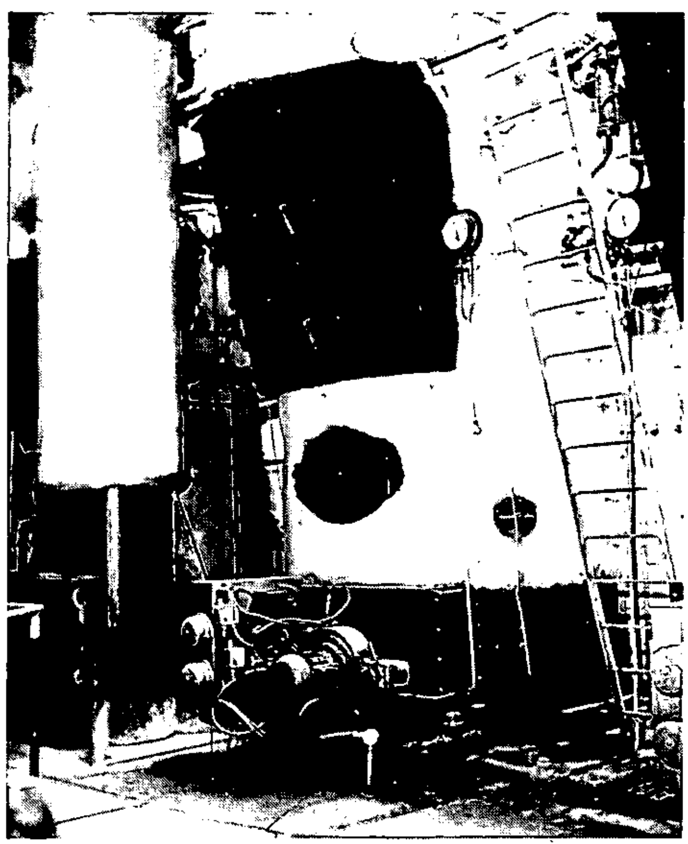


Fig. 4 Boiler at Portwey Hospital

POST CONVERSION LABOUR REQUIREMENTS

Plant 1 and Plant 2—Damers Geriatric Hospital and Dorset County General Hospital

Since the satisfactory conversion of these two steam-raising plants, the labour force has been reduced from the original eight boilermen to two attendants for both installations, regraded as semiskilled fitters.

They work a 5-day, 40-hour week on continuous shift between them as follows:

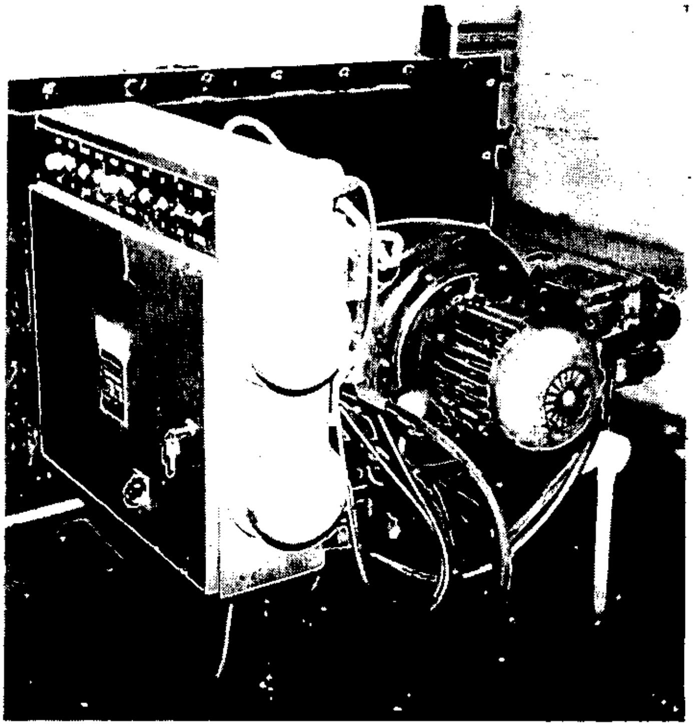


Fig. 5 Burner at Portwey Hospital

	Friday	*Saturday*	*Sunday*	*Monday*
Shift 1	7–4	7–4	7–4	7–4
Shift 2	8–5	n.r.d.	r.d.	8–5

	Tuesday	*Wednesday*	*Thursday*	*Total*
Shift 1	7–4	n.r.d.	r.d.	40 h
Shift 2	8–5	7–4	7–4	40 h

(n.r.d.—nominated rest-day)
(r.d.—rest day)

Daily duties—shift 1–7 a.m. to 4 p.m.

7–8 a.m. boiler safety checks, blow-down gauge glasses and control systems. Test feed water and add water treatment, maintain plant log

8–1 p.m. various duties throughout the hospital as directed by the engineer

2–2.15 p.m final check of plant, change over to night-alarm system and inform telephonist of attendant on call

2.15–2.30 p.m. walk to Damers Hospital

2.30–4 p.m boiler safety checks, blow-down gauge glasses and control system. Test feed water and add treatment, maintain plant log. Change over to night-alarm system.

Daily duties—shift 2—8 a.m. to 5 p.m.

Report for duty with other members of the works department for general hospital maintenance

Plant 3–Portwey Hospital, Weymouth

The shift arrangements are now similar to those at Dorset County and Damers Hospitals, Dorchester. As, however, only one steam-raising plant is involved, the staff has been reduced from the original four boilermen to two attendants, regraded to semi-skilled fitters.

COMPARISON OF PRE- AND POST-CONVERSION COST

Owing to the high rate of inflation in the years following conversion, the comparisons are made of pre- and post-conversion staffing and fuel consumption at present cost.

Labour

Plant 1 and Plant 2

Pre-conversion: 8 boilermen at £2 500 p.a	£20 000	
Post-conversion: Two semi-skilled, of which only one man is on boiler duty, and less than half of this is charged to boiler maintenance, 50% of £2 750 p.a.	£1 375	
Actual saving =	£18 625	93%

Plant 3

Pre-conversion: 4 boilermen at £2 500 p.a.	£10 000	
Post-conversion: Two semi-skilled as above, 50% of £2 750	£1 375	
Actual saving =	£8 625	86%

Fuel

Plant 1

Pre-conversion: 209 tonne at £30/tonne.	£6 270	
Post-conversion: 148 480 l at 4·4p/l	£6 533	
Excess	(263)	(4·2%)

Plant 2

A new unit has been added; therefore a true comparison cannot be made; however, the extra cost of 35 second fuel oil to medium would be:	Excess	(£1 006)

Plant 3

Pre-conversion: 817 240 l at 4·1p/l		£33 507
Post-conversion: 587 232 l at 4·3p p. litre		£25 251
	Actual saving	£8 256 = 24%

Services

Post-conversion: Plant 1—electricity increase	(£88)
Post-conversion: Plant 2—electricity saving	£255
Post-conversion: Plant 3—electricity increase	(£324)
Post-conversion: Plant 3—a noticeable saving in main-feed make up. Saving=	£67

Summary of annual financial savings

A consolidated summary of the saving previously detailed is shown in Table 1.

Table 1

	Plant 1 & 2	Plant 3	Total
	£	£	£
Labour	18 625(93%)	8 625(86%)	27 250(91%)
Fuel	(1 357)	8 256	6 987
Electricity	255	(324)	(157)
Water		67	67
	£17 523	£16 624	£34 147
Capital cost of conversion	£5 478	£5 194	£10 672

Pay-back with no inflation

In a period of stable wage rates and fuel cost, the saving would not have been less than the following:

Labour (1972)		£
Plant 1: 3 boilermen at £1 560	4 680	
Plant 2: 3 boilermen at £1 602	4 806	
Plant 3: 2 boilermen at £1 602	3 204	
		12 790
Fuel (1972)		
Plant 1: Saving on fuel to coal price	1 332	
Plant 2: Saving on electricity	207	
Plant 3: Saving on fuel-oil consumption	2 777	
		17 106
Fuel (1972)		
Plant 1: Excess electricty	88	
Plant: 2 Excess fuel oil, light to medium	785	
Plant 3: Excess electricity	275	(1048)
		15 958

Taking this crude calculation on the assumption of no increase between 1972 and 1975, the capital cost of converting the three plants would have been recovered within nine months

Conclusions

It will be seen that, for a relatively small capital outlay of £10 672, three hospitals' steam-raising plants have been successfully converted to more efficient automatic units, and no doubt given a new lease of working life.

Furthermore, the capital involved has been actually recovered within twelve months, and each year thereafter considerable savings in materials and maintenance cost to an approximate sum of £34 000 will accrue at present prices. Some additional comments

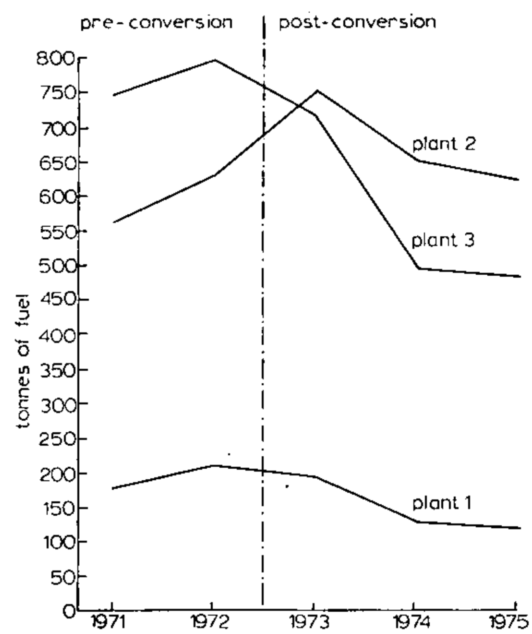


Fig. 6 Fuel consumed 1971-75

Table 2 Characteristics of boiler fuels

Plant	Solid fuel 1 Damers Hospital	Medium fuel oil 1 and 2 Dorchester and Portwey	Gas oil (light) all plants
Specific gravity at 15·5°C		0·95	0·835
Viscosity Redwwood No. 1 at 100°F		1000 second (treacle)	35 second (diesel oil)
Minimum storage tempatature		38°C	
Minimum combustion temperature		82°C	
Calorific value per kilogram	33 MJ/kg	42 MJ/kg	45 MJ/kg
Sulphur content, maximum % by weight	2	3·5	0·75
Ash content % by weight	5	0·12	0·01
Current price	£30 per tonne	£50 per tonne	£52·30 per tonne

on this saving and other important aspects are given below:

Labour

The major saving is in the cost of labour: requirements having been reduced by not less than 66·6%. It should be mentioned that this reduction was achieved by natural wastage and regrading to semiskilled on the general maintenance works staff. A recent interview with the regraded staff brought forth the following important nonfinancial aspects:

(i) a new interest and sense of responsibility in the steam-raising plant (seven days in complete control)

(ii) more active and healthier employment, in two cases the loss of two stones in weight

(iii) the opportunity to work with other tradesmen in different hospitals and various departments

(iv) all three boiler houses have been redecorated since conversion by the regraded staff, thus improving the working environment.

Table 3 Comparison of fuel properties in the three plants

Fuel	Advantages	Disadvantages
Gas oil	(i) Suitable for unmanned plants (ii) No preheating required (iii) Clean combustion (iv) Low sulphur ash content (v) High calorific value (vi) Low maintenance cost	Expensive
Medium fuel oil	(i) Cheapest fuel oil	(i) Not suitable for unmanned plants (ii) Requires pre-heating in storage and before combustion (iii) High sulphur and ash content; more susceptible to soot fall out (iv) Higher maintenance cost
Solid fuel	(i) Cheap and readily available	(i) Not suitable for unmanned plants (ii) High sulphur and ash content more susceptible to soot fall out (iii) Low calorific value per kilogram

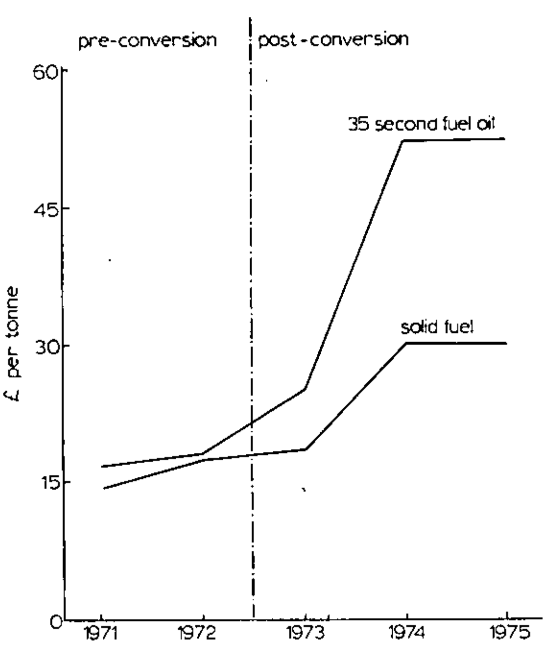


Fig. 7 Price of fuel 1971-75

Fuel

At each plant there has been an improvement in the efficiency and burning of fuel. Fuel characteristics and comparisons are given in Tables 2 and 3.

The change to light oil has also stopped the smoke and soot problems in the vicinity of Dorchester and Portwey Hospitals, thereby improving the relationship between the hospitals and the local residents; which had caused concern in the past.

Plant 1—Damers Geriatric Hospital

Although it is difficult to compare solid and oil fuels, there has been a reduction in tons used (see Fig. 6). Also, the automatic burner controls maintain the boiler at a constant pressure, far superior to the standard maintained by manual-fired solid fuel.

Plant 2—Dorset County General Hospital

As this was a modern plant, the savings are mainly in maintenance and electricity, and although an extra hospital unit has been added, the fuel consumption has fallen steadily (see Fig. 6).

Plant 3—Portwey Maternity Hospital

This proved to be the most successful fuel-saving operation, mainly due to the automatic burner control and the saving of an estimated 15% of steam capacity used in combustion and pre-heating the fuel oil.

From Fig. 6 it can be seen that there has been a major drop in fuel used.

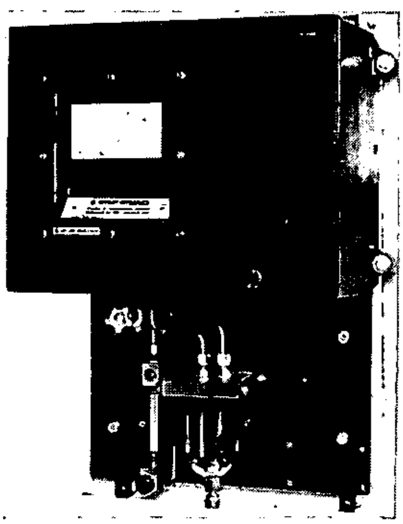
Recommendations

In the light of the proven considerable advantages summarised in the previous sections, it is strongly recommended that manually operated steam-raising installations should be thoroughly surveyed regarding adaptability and working life and serious consideration given to their early conversion to automatic operation in the National interest of fuel conservation (see Fig. 7 for fuel price increases), and the rising cost of labour.

Product news

Combustibles analyser

The OCA.369 is an industrial analyser that continuously reads oxygen and combustibles. The oxygen analyser has five switched ranges from 2·5 to 25% O_2, and the combustibles analyser has two switched ranges 1% and 5% CO. Both millivolt and milliampere outputs are available for recording or automatic control.

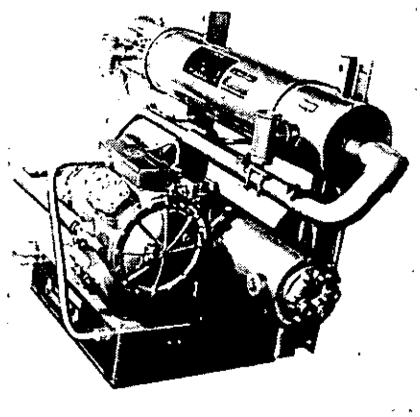


Using these measurements the fuel/air ratio can be accurately set to give maximum firing efficiency and a reduction in fuel bills. To help engineers obtain maximum boiler efficiency, the company has produced an application note *Flue gas analysis* and a fuel-efficiency slide rule.

Taylor Servomex Ltd., Crowborough, Sussex

Heat pumps

Dunham-Bush Ltd. has published a 3-language bulletin describing the range of heat pumps now being manufactured. The pump has been designed to provide high performance-efficiency ratios by utilising a refrigeration system and constant heat source in the evaporator. By maintaining a balance at the evaporator, a constant thermal energy transfer to the condenser is obtained which rejects the heat from the refrigerant to the water which is circulated through the condenser. Low-volume, high-temperature water is pumped through a 2- or 4-pass arrangement to terminal units or underfloor heating or hot-water services. The addition of a twin circuited system can be used



to provide heat for both domestic heating and swimming pools. The bulletin, HP1, describes the operation of the heat-pump principle in English, German and French and includes the principal operating characteristics of the seven models in the range, with heating capacities up to 68·8 kW.

Dunham-Bush Ltd., Fitzherbert Road, Portsmouth, Hants, PO6 1RR

Multi-fuel boiler

The Crusader multi-fuel boiler provides outputs from 132 to 439 kW and has been introduced to offer an answer to the vagaries of fuel-pricing policy. It can be fired by oil or gas burners, or by solid-fuel mechanical stokers. An efficiency level of 75 to 80% is quoted, depending on the type of fuel and firing system used. There are nine sizes in the range, each fitted with 10 cm flow-and-return connections, the former being sited at the top of the front section and including temperature and altitude instrumentation.

The Beeston Boiler Co. Ltd., PO Box 2, Beeston, Nottingham NG9 2DN

Patient isolator

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Capecraft Ltd., Cape Road, Warwick CV34 5DL

Nurse call

The VH-125/155 series consists of two types of master unit, both of which come in five capacities and will cope with up to 60 connectable stations. The remote unit can pick up a patient's voice from a distance of up to 6 m, therefore only one remote unit is needed in a room of 2 or 3 patients, and a corridor lamp and re-set switch. The system is designed so that a patient's call is continuously signalled until a nurse replies to it, and even when the master unit is occupied, calls from other patients are registered by station lights. Power is supplied to the system from mains and/or a 24 V d.c. supply. If there is a power failure, then the supply is automatically switched over to the battery.

Teletronics Ltd., 9 Connaught Street, London W2 2AY

Light conversion

This kit enables standard fluorescent lighting fittings to be converted to provide automatic emergency lighting. It was originally designed to meet Post Office specifications. It consists of two interconnecting packs that will fit into standard batten fluorescent fittings. One pack contains a constant-current charger, solid-state switching device and transistor invertor unit; the other contains the sealed nickel-cadmium battery. The kit is supplied with a 3 cm 8-W miniature fluorescent tube, lamp leads and terry clips. After installation, the fitting will automatically switch to the emergency power on mains failure. Minimum duration of the battery after 24 hours recharge is 2 h and the nominal light output is 200 lumens.

Security Lighting Ltd., 27 Breakfield, Ullswater Crescent, Coulsdon, Surrey

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