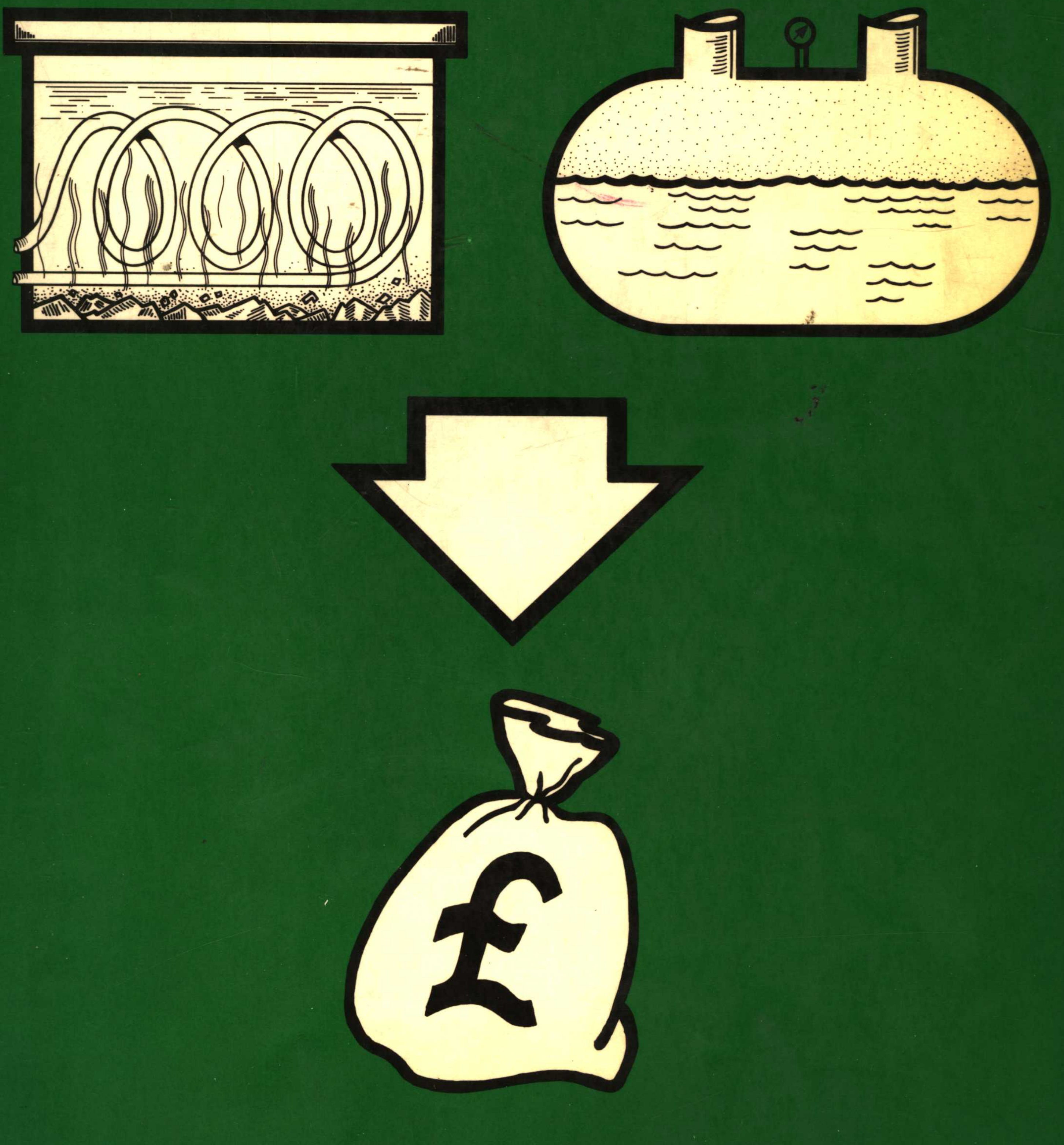
Papers presented at the
2nd BHRA Fluid Engineering International Conference on

Energy Storage

ENERGY STORAGE FOR ENERGY MANAGEMENT



Stratford-upon-Avon, England
May 24th-26th, 1983

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Editors: H S Stephens
Mrs G B Warren

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ENERGY STORAGE AND STORAGE EFFECTS IN INDUSTRY

H. B. Weston, AHWC.,C.Eng.,M.I.Mech.E.,F.Inst.E.

National Industrial Fuel Efficiency Service Ltd

NIFES House

Sinderland Road, Broadheath, Altrincham, Cheshire.

WA14 5HQ

Summary

The increase in energy cost in real terms has had a profound effect on company profitability and highlights the need for energy cost reduction. Peak energy demand and the effect on plant capital cost has been well recognised in the past by incentives offered by the Electricity Authorities to reduce maximum demand. The advantages are thermal storage in hot water and steam are discussed by reference to simple storage systems stressing that these are not simply storage vessels but systems which, by absorbing peak demand, allow the heat generating plant to operate under favourable load conditions. The trend toward greater use of coal is felt to open greater prospects for energy storage systems and the author stresses the importance of the space heating field as an area affording much scope for energy storage. However, in common with industrial processes the prime consideration should be to firstly design for minimum energy requirement. The use of low mass ceramic fibre insulation and its effect in reducing "stored heat" in furnace structures is given as an example of how our ideas of combined storage and waste heat recovery system can be influenced.

Many processes embody a high degree of energy storage and a plea is made for minimising standing losses particularly in intermittently operated plant. Because energy storage systems are generally capital intensive, the author feels that in the present economic climate investment incentives should be given to extend the use of energy storage systems.

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1. INTRODUCTION

Over the past decade energy prices have increased in real terms (see Fig.1) to such an extent that in many industries the 'energy cost' approaches and even exceeds the profit level. A 1% reduction in energy cost may therefore, represent more than a 1% gain in profitability and energy storage systems can assist in improving energy utilisation efficiency and reducing costs.

In industry the demand for energy, whether for process, space heating and power production is seldom, if ever, constant. Heat generation capacity therefore, must be large enough to deal with the peak demand problem. Often this requires that capital investment in plant is inordinately high because of the incidence of poor load factor and, since costs are a combination of capital and running charges, this is reflected in the cost of energy; also, poor load factor may cause operational problems which can affect plant efficiency and lead to increased running costs. Indeed, the mixture of capital and running cost is the basis of the two-part tariff system which is used by the Electricity Authorities for charging electricity costs, i.e. a charge based on electrical maximum demand plus a running charge based on electrical units consumed. Thus, the user is encouraged to reduce his maximum demand or improve load factor which assists the Authority to optimise the use of capital plant.

The energy storage field is vast and its potential great. What follows simply touches on some aspects which the Author believes are particularly relevant.

2. IMPORTANT CONSIDERATIONS

2.1 It must be recognised that the Industrial scene is one of change and frequently plant or equipment must be adapted to the changing conditions. Industrial processes too, may change, and the likelihood of this is reflected in the pay-back period for new or modified plant and this must be understood by all who are concerned with energy saving in which energy storage can play a vital role. The solution to energy storage problems depend largely on local circumstances.

2.2 The importance of the problem of storage and its effect on capital plant capacity is evidenced by Fig 2 which shows the approximate monthly energy consumption trend for the U.K. derived from official statistics (Ref.I)

The base line indicates the energy demand to meet normal production needs and the shaded area represents the additional demand during Winter. It will be seen that the total energy consumption in peak Winter months is greater than in Summer by a factor of some 1.5 and is almost identical for both years considered. But it is known from extensive industrial surveys that load factor on services plant even in Winter is less than 50% if standby capacity is included and this gives some idea of the enormous unused capacity which exists during the non-heating season. This must surely represent poor utilisation of capital resources in the national economic sense caused wholly by the peak demand heating problem.

2.3 Thermal storage systems are often needed as an energy sink to absorb surplus energy when demand is low or to act as load smoothing devices, often in conjunction with waste heat recovery. Although energy storage in the proper sense involves a change in pressure or temperature, volume or state or a combination of these, it would be unwise to omit mention of another problem of storage in Industry, viz. energy inadvertently stored in processes either by their very nature or by virtue of their design and which are major causes of energy inefficiency.

3. HISTORICAL

3.1 Energy storage is certainly not a new concept in Industry. The fuel supply industry are obliged to practise energy storage as physical stocks by Tankage, gas-holder, stockpiling etc., as a buffer between supply and demand.

In Industry one of the commonest methods of energy storage has been as sensible heat in low-temperature hot water systems or in high temperature (pressurised) water systems. Readers will be aware of the use of regenerative heating in reverberatory furnaces where chequer-brickwork is alternatively heated by the furnace exhaust gas, and then cooled in preheating combustion air. This system is still in extensive use in the glass and metals industries. It is a good example of energy storage as sensible heat in ceramic material developed originally for preheating of fuel gas and combustion air which could be done in regenerators more reliably than the early type of high temperature recuperator.

A similar principle is embodied in the well-known rotary preheater developed by Ljungstrom and now known as the 'heat-wheel'.

3.2 In the 'clay' industries heat-stored in the burned-ware has been utilised for preheating/drying of green ware and the principle is embodied in both chamber and continuous tunnel kilns.

3.3 Other examples of energy storage systems are the use of fly-wheels, regenerative braking, electric storage batteries, hydraulic accumulators, pumped storage etc., to mention but a few.

4. PEAK LOADS

4.1 The whole field of energy storage is inevitably concerned with supply and demand or waste energy available for recovery but out of phase with the demand. A paper on energy storage however, would not be complete without reference to 'peak' load or demand for it is this which usually makes consideration of some storage system necessary.

		Period
a.	Due to variation in space heating load or in some agricultural industries due to seasonal crop output.	Months
b.	Due to change in space heating load with change in outside temperature.	Days
c.	Due to process load change, e.g. main process users coming on or off stream.	Hours
d.	Due to time-cycle control of process operations such as autoclaves etc.	Minutes
e.	Due for example, to hunting or action of auto-control valves, cyclic variation etc.	Seconds

4.2 In any consideration of energy storage it is the area under the demand profile or curve which represents the energy to be stored or given up and although in categories d. and e. the peak demand may be very high, the quantity of energy involved in usually small because of the very short time base. Often such variation in demand can be absorbed by the system capacity although they may give rise to undesirable operating conditions. Peak demand variation a, b and c, however, are much more serious in view of the larger amount of energy involved which must be provided for either in terms of plant capacity or some system of storage.

The above may appear self evident but it is worth stressing in view of the remarks often made in Industry regarding the extent of peak demand or load swing which often refer loosely to the level of demand and not quantity of energy involvement.

5. THERMAL STORAGE

5.1 Where steam is used in process at pressures below the boiler supply pressure or where hot water is required in large quantities, the opportunity arises of storing energy as a means of reducing the peak demand and therefore boiler capacity. Heat is transferred to water in both cases either with constant water volume/variable temperatures or variable volume/constant temperature or variable volume/variable temperature. Since the hot water storage system normally works at low pressure, these are cheaper to construct than steam storage vessels and where large quantities of hot water are required, a hot water accumulator should always be considered.

5.2 A typical arrangement is shown in Fig. 3, cold water entering a vertical storage tank 3m. dia. x 10m. high heated by the exchanger which, at periods of maximum water draw-off from the top of the vessel, is capable of heating all the water required. Cold water enters at the base of the tank; the boundary layer between the hot and cold moving progressively up the accumulator. Thus the peak demands for hot water are satisfied whilst maintaining a steady load on the boiler plant, the thermal efficiency of which can be optimised. A similar arrangement has been used successfully in high pressure hot water systems where severe peak demands are imposed from process-presses.

5.3 A slightly different, but effective system of energy storage is shown in Fig. 4 which utilises process condensate in a variable volume system for preheating milk in a central exchanger supplying batch evaporators. Before the installation of this system the milk was preheated by steam exchanger which imposed a significant peak demand on the system of 1.7 t/h sufficient to cause overload problems which were completely eliminated by the storage system, allowing more efficient operation of the boilers. The reduction in condensate temperatures was more than offset by the installation of additional economiser sections on the boiler.

5.4 A great advantage of energy storage as hot water is the facility with which it can very often be integrated with waste heat recovery and indeed, in many industries such as Textiles, Brewing, etc., hot water energy storage systems are an inherent part of the waste heat recovery system.

5.5 The above actual examples are of simple systems which were economically justified and which are true energy storage systems in the proper sense and are given to emphasize the fact that a thermal storage system is not a storage vessel but rather a storage facility which enables high process demand to be satisfied whilst enabling the boiler plant to operate at relatively constant load. It is worth noting also that such systems serve as an excellent 'heat sink' for absorbing waste steam such as steam-trap flash vapour which is often wasted because no suitable or convenient use can be found for it.

6. STEAM STORAGE (Steam Accumulator)

6.1 Despite its drawbacks, steam is still one of the cheapest and most flexible heating mediums at our disposal and the commonest form of heating in the process industries.

Very few industries operate under steady load conditions and many suffer from severe load swings, e.g. Dyeworks, Breweries, Rubber Vulcanising, Pulp digestion, Safety-glass autoclaving, Plastics autoclaving, to mention a few. Often rapid load-swings will present severe boiler operating problems including; loss of pressure, boiler water carry-over and reduction in thermal efficiency. The problem was much greater pre-1970 when most plants in this country were coal-fired. The ability of a boiler to cope with change in load depends on its inherent storage capacity, i.e. water content and permissible pressure drop, and on the rate of response of the firing appliance or stoker. Some stokers do not possess a fast rate of response, e.g. retort stoker, chain grate etc., so that the occasion of a sudden demand may cause acute pressure drop until the stoker has caught up with the load and conversely sudden load reduction may cause rapid pressure rise and blowing of safety valves. Under such conditions it is difficult to maintain optimum combustion conditions, i.e. low excess air, and this occasions further loss in efficiency due to increased flue gas loss. Staggering of loads can reduce the need for storage but where this is impracticable steam storage can be very useful. In view of its importance as a storage device it is considered that further explanation of the steam accumulator is warranted.

6.2 Water in a boiler is at the same temperature as the steam being generated but there is an important difference. Steam contains latent heat of evaporation whereas the water contains only the sensible heat, e.g. when a boiler blowdown valve is opened to drain, the pressure is reduced to atmospheric and because water at this pressure simply cannot contain as much sensible heat as the water at boiler pressure, the surplus energy is flashed-off. The lower the back-pressure, the greater the amount of steam 'flashed-off'. Water at boiler pressure and temperature therefore, is a means of storing heat or steam, i.e. if the pressure can be allowed to vary, and this quite simply is the action of a steam accumulator. In practise the accumulator is a pressure vessel about 3m dia. by about 9m long nearly nine-tenths full of water with automatic pressure controls arranged so that when boiler pressure rises fast, the steam 'surplus' valve opens and injects steam into the accumulator via the injection pipes, so increasing the accumulator pressure. Conversely, when the process steam demand rises suddenly, the surplus valve closes and allows the accumulator to 'discharge' into the process main and as the steam is 'flashed-off', the accumulator pressure falls.

In order to operate the system effectively there must be a significant difference in pressure between the boiler and process. Furthermore, the steam pressure in the accumulator must vary - if it does not, then the accumulator can do no useful work at all. There are several ways of installing steam accumulators but Fig. 5 shows a common arrangement for dealing with low pressure peak loads. By allowing the accumulator pressure to vary, these devices can be very successful (sometimes essential) in meeting 'peak' demands or load-smoothing. In some instances the 'peak' load may be over twice the average load and a steam accumulator can enable the boiler capacity to be fixed closer to the average rather than maximum demand, thus reducing boiler capital costs.

6.3 One is justified in querying why in spite of their advantages steam storage devices are less common today and it is important to state the reasons for this. The advent of cheap oil resulted in enormous developments in the design of oil burners. Whereas coal/oil conversions of the early sixties used the relatively inflexible pressure jet burner, this was rapidly superseded by the modulating spill jet and rotary cup burner operating under fully automatic control. Where such burners were installed in boiler plants operating in conjunction with accumulators, it was generally found that the speed of response to pressure drop was so good that the burner would invariably 'grab the load' and the accumulators (some were simply converted shell boilers) were therefore removed; and yet, this problem could have been easily overcome by a simple modification to the steam accumulator controls which, by steadying the boiler load could have permitted tight control of excess air by reducing the burner flame-swing.

A factor which was sometimes overlooked was the ability of the steam accumulator to supply a small night steam load and so allow the boiler to be shut down, rather than requiring the burner to be flashed up intermittently on very low load which is not conducive to high efficiency and is also prone to cause smutting with oil-firing.

6.4 Storage Effect

The change in enthalpy of the saturated liquid maximum pressure and minimum (discharge pressure) equals the latent heat gained by the steam and thus it is a simple matter to calculate the storage capacity of a steam accumulator if the water content and pressure range is known. For example, it can be shown that a vessel containing 20 tonnes of water charged to 10 bar gauge (145 psig) and allowed to discharge to 2.07 Bar (30 psig) will produce nearly 2 tonnes of low pressure steam and this could represent a draw-off rate equal to:-

a. 200 kg/hr for 10 hours
b. 2 000 kg/hr for 1 hour
c. 20 000 kg/hr for 0.1 hour (6 minutes)

One can appreciate from this the great potential for meeting 'peak' loads. It must be stressed that there are limitations on draw-off rate due to water entrainment. Note that although in the above example the total energy stored is the same, the rate of draw-off varies by a factor of 100.

It is often overlooked that with steam, a drop in pressure results in an increase in specific volume and thus the pressure drop in the distribution system is increased which may cause consumers to demand more steam which further increases the peak load or, alternatively, some process consumers may be starved.

6.5 Before considering storage systems the nature and source of the peak demand should be carefully investigated, often modifications to process cycles or use of critical or limiting orifice plates can make marked reduction in the magnitude of the peak at the source. Automatic controls are often the cause of peak loads, particularly if faulty or oversized, this applies equally to process consumers and boiler plant.

6.6 Accumulators of the above type can handle variation in demand lasting minutes or hours in duration and in view of the increasing role which coal may be expected to play in future, it would mean that greater use might be made of such devices.

7. FEED-WATER STORAGE

7.1 The above refers to steam systems but important application of energy storage in the form of feed-water at boiler pressure is exemplified in the Keisselbach and Marguerre accumulators. The latter is very similar to the example of the hot water storage accumulator already referred to, except that the water is used for boiler feed. These may have particular application for keeping back-pressure power plant in balance as well as improving the overall cycle efficiency. The Keisselbach accumulator on the other hand operates at fixed temperature (saturation temp.) and is virtually an extension of the boiler drum, both types are essentially devices for smoothing out high pressure peaks.

7.2 It is fair to say that the development of automatic controls and in particular automatic burners, have, to some extent undermined the case for these devices except in large installations where they may be desirable for operational reasons alone. It is fitting however, to mention that the same principles have been embodied in some shell boiler designs notably the Storage boiler (developed by Danks Limited). This boiler in principle has extra large water content which is allowed to vary over wide limits and provides substantial peak-load carrying capacity.

8. FALSE 'PEAK' DEMAND

8.1 It is important to differentiate between true variation in energy demand and those which may be apparent or artificially induced. A common example of this on modern boilers is exemplified in Fig.6 which shows a demand for steam with severe apparent 'peak' loads, which have nothing to do with process energy demand at all! The 'load' on a boiler is not measured by the steam flow at the stop valve; the fuel burner is regulated by the demand for heat and this depends not only on steam flow, but on feed water flow and feed temperature.

8.2 In any steam boiler, water must be raised to saturation temperature before vaporization can be effected. This is clear from the following table:-

Table 1. Comparison of figures for two similar boilers.

Steam load kg/hr	Feed Temp. ^oC	Heat above Feed Kj/kg	Total Heat Demand Mj/hr	
5 000	65.5	2 494.8	12 474	Boiler A
5 000	170.0	2 050.0	10 250	Boiler B
			Diff= 2 224	

Note that on Boiler 'A' because of low feed temperature, the fuel burner load is some 21% higher than Boiler 'B' although the steam demand is identical. Indeed, on Fig.6 the 'peak load' is simply the result of poor feed regulation (hunting of feed regulator due to oversize) and the sharp drop in steam output is caused by the sudden chilling action of the feed-water slug when the regulator opens and this is reflected in the steam pressure variation or ripple shown on the chart! It is clear also that the burner very frequently operates under 'full load' conditions when in fact the average load is little over 50% of the boiler rating. Although modern burners are good, it is not easy to tune the system to optimum fuel/air ratio and often excess air is greater than need be; also, cyclic stressing of boiler tube plate is accentuated with inevitable increase in maintenance cost; furthermore the boiler water density (TDS) may require to be kept lower than need be to prevent water level surging (carry-over) and this may result in increased blowdown loss. The apparent 'peak' load problem is often compounded by poor design of pipe connections where boilers are coupled to a common header.

9. OTHER KINDS OF 'STORAGE'

9.1 Most industrial processes are in point of fact energy storage systems by virtue of their design and construction in that they contain a great deal of stored energy, this is particularly true of intermittent processes such as furnaces, autoclaves etc. Also, every boiler is an energy storage system, the amount of energy depending on water content and temperature. Where storage is inherent every effort should be made to ensure that energy losses are minimised by using high standards of insulation.

9.2 In the commercial sector particularly, heating boilers operate intermittently and insidious losses may occur for example due to ambient air passing through the boiler/burner system during the 'off' periods. The following data taken for site tests on different central heating boilers shows how thermal efficiency is affected by variation in energy demand.

Range of Boiler Size 1700 kW - 2900 kW, Fuel Heavy Oil

	Burners Type	Purging/ Standing Loss %	Stack Loss %	Radiation Loss %	Thermal Efficiency	Load Factor
Plant A	Modulating	5.2	16.1	12	66.7	15.5
Plant B	Modulating	3.1	15.3	5.4	76.2	28.2
Plant C	Modulating	3.4	16.1	14.2	66.3	11.3
Plant D	High/Low	11.7	24.2	5.0	59.1	34.1

These boilers are all capable of operating at thermal efficiency in the order of 80% when operating under reasonable load conditions. Plant 'D' was over-burned and simply required a smaller burner jet. But no amount of firing can offset poor insulation or excessive cooling loss due to air passing through the boiler when idling nor the loss due to forced cooling due to pre and post purging of the burner. Such purging of course is essential on grounds of safety but the data emphasizes the need for good automatic isolating flue dampers with appropriate safety interlocks to reducing depletion of 'stored' energy. Of particular note in the above table is the poor load factor (basically the system-demand divided by the output which the heating plant could give when operating at its M.C.R.) In the above table daily load factors are given but the overall seasonal load factor is even worse than indicated. This underlines the enormous under-utilisation of capital plant,in the cases quoted above, the heat generating plant each day is idle for nearly 15 hours out of 24 hours.

9.3 The Electricity Supply Industry have vast capital sums tied-up in generating plant and improvement in the National load factor is of great significance in reducing the influence of capital charges on power produced. 'Off-peak' electricity at about half the cost of 'peak' power is offered as an inducement to use electricity at night when the national demand is low. The development of electrical energy storage heaters (using ceramic or C.I. packings) resulted in a rapid growth of this type of heating commencing in 1960 to about 17 000 MW of installed capacity by the end of 1974.* Having regard to the fuel price trends given, it would seem that 'off-peak' power presents an even greater attraction now and this must surely stimulate the development of electrical storage systems or combined fossil fired/electric systems for building services particularly in view of the growth of 'intelligent' solid state devices for sensing temperature trends and optimising heating start-up/off times. *(Ref.II)

10. REDUCING THE 'HEAT STORED'

10.1 Heat storage problems (and associated losses) in Industry are prolific but basically can be divided into:-

a. Energy stored in process vessel fabric, e.g. furnace or kiln structure.
b. Energy stored in product or processing medium at the end of the cycle.

The problem is often how best to dissipate the stored energy.

Inevitably such losses lead to considerations of waste heat recovery which usually involve a storage system of some kind be it steam, bot water or solid storage in the form of chequer brick, and the capital cost of the recovery system will often largely depend on the amount of waste heat available.

10.2 It is vital to produce an energy balance of the system, for in the process of doing so, the direction in which we might proceed is often radically altered. The Author makes no apology for including a few simple examples to underline the importance of an aspect of storage which is often overlooked!

10.3 In the metals Industry, the primary fuel demand on a furnace is a function of waste gas loss and fabric loss of which heat stored in brickwork may be a significant item. This can be illustrated by reference to a small fuel fired furnace consuming 300 kW with a waste gas loss of 65% or 185 kW which suggested useful potential for water heating for which there is a demand. Fig.7 shows the energy balance before and after (a) improving burner combustion performance, (b) using low thermal mass ceramic insulation to reduce steady state and storage loss, and (c) fitting a combustion air preheater. Fuel consumption is reduced from 300kW to 96kW and waste gas heat loss from 185 to 51kW. Waste heat available for recovery is reduced to less than $\frac{1}{3}$ of its original value and the thermal efficiency of the process vastly improved. Had a waste heat exchanger been fitted in the first place, subsequent improvements would have been inhibited, or, alternatively the waste heat recovery system would become redundant on improving the furnace performance.

10.4 A few years ago NIFES were involved in a process employing 9-3m dia. by 9m long digesters which were raised from ambient to 10 Bar, (by steam). The cycle time was approximately 10 hours and at the end of the cycle the digester pressure required to be relieved to atmosphere before emptying product. The initial charging imposed severe peak loads on the system which resulted in inefficient operation of the coal fired boilers. The water charged per vessel was approximately 9t and several schemes were considered involving (a) hot water storage; (b) hot water storage combined with 'flash' heat recovery from the digester blowdown, and (c) central hot water storage derived from a process economiser in the boiler plant. Steam storage was not possible as the digesters operated at nearly boiler pressure.

10.5 Considering the multiplicity of units and the difficulty of phasing 'flash recovery' and also potential fouling problems, scheme (c) appeared the simplest solution and the most economic.

The heat balance clearly indicated that the principal energy requirement was for heating water, the use of which was mainly as a transport medium for charging the vessel and not really a process reaction requirement. The client developed the use of a chemical lubricant which enabled the raw material to be pumped as a thick slurry and the primary energy demand dropped from 10.4GJ to 5.3GJ/Batch. This reduced the number of boilers on the line from 5 to 3 thus effectively overcoming the energy storage problem by eliminating or drastically decreasing the stored energy! The process cycle time was also reduced to about 5 hours.

10.6 The development of low-mass ceramic-fibre, high temperature insulation has had a significant impact in reducing thermal storage losses associated with furnaces and kilns particularly those of the intermittent type. Ceramic fibre linings are approximately 75% lighter than insulating firebrick and about 95% lighter than ordinary firebrick.

New furnace structures can be built with considerably reduced structural support thus releasing the designer from the constraints of traditional design. An example of the effect of such insulation is the case of an intermittent bogie-hearth furnace operating at 1050°C, in the heavy engineering industry. The fuel consumption of this furnace was reduced by 30% after application of ceramic fibre insulation.

In many kiln operations not only is there a considerable thermal storage loss in the structure and fired ware but the storage loss in kiln furniture can be considerable, e.g. in the operation of tunnel kilns the kiln cars, because of their massive structure, can absorb a considerable proportion of the heat input - in some cases up to 10%. The use of hot face insulation and ceramic fibre on the car bases has produced savings up to 5%. (Ref.III).

Even in intermittent kilns the storage losses can be reduced by collecting and ducting the kiln cooling air for drying purposes but in some sections, e.g. Potter industry, the drying operation can be seriously out of phase with the waste heat flow and here there is still some potential for storage systems of the regenerative chequer brick type.

11. SUMMARY AND CONCLUSIONS

11.1 A cardinal rule governing the consideration of energy storage systems is firstly to fundamentally review the energy requirement of the process with a view to reducing the 'work to be done' or amount of energy needed.

11.2 Energy storage systems should not be used to sustain processes which are inherently inefficient and in this connection it is necessary to underline the need to reduce storage losses in many processes particularly those which operate on an intermittent basis.

11.3 Energy storage systems involve detailed consideration of the variation in the energy supply and demand situation. Such systems can be costly and for this reason detailed survey and measurement of all the variables is absolutely essential in deriving a satisfactory economic solution. There is no short-cut to this procedure.

11.4 An elementary step sometimes overlooked is re-scheduling or staggering of energy demands and whilst the situation in Industry often limits how much this can be done, it is a prior consideration. The use of the computer or micro-processor in programme or work-scheduling is a powerful tool in this sense. Electrical power utilisation offers a great challenge not only in terms of new storage systems but rather in reducing the need for them. Central load-control systems are one example of the application of this technology as an aid to controlling maximum demand in Industry.

11.5 Modern life-style, by its very nature has profound influence on the energy storage problem and efficient energy use, be it space heating, transport or electrical demand. Life-styles will not change quickly but it is clear that the space heating field is an area offering considerable scope for energy storage and storage systems combined with waste heat recovery,with the above proviso of first designing for minimum energy requirement.

11.6 The long term future for coal will probably increase the use of thermal storage systems such as the 'steam accumulator' or feed water accumulator, although here again, the storage characteristics of boilers should be appraised with this in mind and boilers are available which possess considerable storage properties.

11.7 One should not under-rate the development of control system devices which can respond to change in load condition much faster than previously and with gas or oil firing, the speed of response has, in many instances, made storage systems unviable but often at the expense of boiler capacity which must be great enough to satisfy peak demand.

11.8 In the long term, energy conservation is vital and indeed the effect of this on stablising the world energy supply/demand situation is already apparent. To Industry the criteria must always be 'cost' and this includes capital, labour and maintenance as well as energy. In view of the economic climate and the short 'pay-back' period required on capital investment, adoption of many energy storage systems is somewhat inhibited.

11.9 Enlightened Governments must actively encourage development and use of energy storage systems and methods of reducing stored energy losses. The present world energy production capacity exceeds the world energy demand, but this is almost certainly a temporary situation

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