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Use and Conservation in the Water Industry

The Institution of Water Engineers and Scientists

1980

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SYMPOSIUM ON ENERGY USE AND CONSERVATION IN THE WATER INDUSTRY

PROCEEDINGS OF SYMPOSIUM HELD IN
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PREFACE

"Save Energy" is a topical catch-phrase of our age, and seldom does a day pass without some reference being made to the energy crisis. Whilst the national and international implications of the diminution and eventual exhaustion of our current natural energy resources are clear to all, the part which the water industry in this country can play in their conservation is not quite so obvious. Furthermore, it is perhaps not yet fully appreciated that the implementation of energy conservation measures can lead to substantial in-house financial savings as well as helping to reduce the overall national energy demand.

The Symposium will cover all aspects of the water, sewerage, and sewage disposal fields from the points of view of the designers of new installations, the manufacturers of equipment, and those who are concerned with the more efficient operation of existing works. Of particular value will be the combined engineering/financial paper which will not only illustrate the significant financial savings which have been made in one Water Authority but also describe how these savings were achieved.

The authors are mainly from within the water industry in this country and speak with experience and authority but the inclusion of a paper from the USA, reflecting current American thinking on energy, will add breadth and depth to the scope of the Symposium.

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OPENING THE SYMPOSIUM

The Rt Hon Tom King, MP

The President, Mr M.J. Lowther, introduced the Rt Hon Tom King, MP, Minister for Local Government and Environmental Services, and invited him to open the Symposium.

Mr King acknowledged his introduction. He said that energy consumption represented about 6% of water authority costs. That might not sound very much but it actually meant that in 1979 water authorities spent over £100m on energy. There was clearly a need, therefore, to make every economy possible, and the use of energy in the industry was obviously a very important area to study. Any savings achieved would help to keep water charges down and so help the consumer, the industry, and the country.

In order to pinpoint where the savings might be made, he would encourage every Water Authority and Company to draw up an energy budget showing the amounts of energy used in their operations. The budget should include each stage from pumping water to final disposal of sewage. This would help to concentrate attention on the areas where savings were likely to be most significant.

There were few certainties in life, Mr. King continued, but surely one was that the price of energy was bound to rise and rise. A £1 saved today might be £2 saved tomorrow. At the same time as energy costs increased, there were pressures on the industry towards greater energy use in future resource development. The need for energy efficiency was therefore all the greater. At the same time, they mustn't get things out of perspective. Energy was just one of many scarce resources and it would be wrong to save energy at all costs. This Government believed that overall efficiency should be maximized. Normal economic appraisal methods should be used in deciding between alternative schemes involving different levels of energy consumption. The important thing was to use the best possible estimate of future energy costs in the appraisal. There were many possibilities for potential energy savings. Some concerned the more efficient use of fuel. Others would result from the reduction of waste of water and excessive consumption. Much was possible using existing technology. It needed energetic application.

Finally, Mr. King urged equipment manufacturers to develop energy-efficient products. Manufacturers must have regard to conditions in other countries if they were to export successfully. Designs should not be based solely on UK needs. The UK was fortunate in having diverse energy resources, but many potential customers had little or no energy resources. The development of energy-efficient products was therefore vitally important if they were to compete overseas.

He congratulated the Institution on organizing a symposium on this particular subject. Few things were more important these days than the conservation of energy, and the more scientific thinking that could be brought to bear on it the better it would be for this country.

1. THE NATIONAL AND INTERNATIONAL ENERGY SITUATION

J.H. Chesters, OBE, PhD, FEng, FRS*

Only once in my life have I ever got twenty out of twenty for an essay. The subject I chose was "The Unique Properties of Water". I had been fascinated by the fact that the liquid we have most of is better suited to our needs than any other liquid I know of, indeed I believe I concluded my essay by suggesting that the properties of water were sufficiently unique to provide strong evidence for the existence of God.

I have no copy of what I wrote, but I remember the main points:

1. Water is one of the few liquids which expands on freezing. If instead it contracted, ice would form on the bottom instead of on the top of lakes and rivers with fatal results for fish and other fauna and flora.

2. Water has, I believe, the highest specific heat of any liquid. If you want to fill a hot water bottle with an equal weight of another liquid, say mercury, you will be worse off. Those who, as of old, resorted to a hot brick to warm their bed would need one four times the weight to keep their feet equally warm.

   The real gains from the high specific heat are however attained in much more vital situations e.g. power generation, heating and ventilating. It also adds greatly to the stability of ocean temperature, which does not fluctuate as rapidly with changes in sun and wind as it would with a low specific heat liquid.

3. It is tasteless and odourless when pure probably because man in his primitive state emerged from water, and long since ceased to notice any taste or odour it might have.

4. It has remarkable solvent powers. When I consulted Van Nostrand's Scientific Encyclopedia while preparing this talk, I was delighted to read that water has 'a distinct position among liquids in the matter of dissolving gases, liquids and solids. While there are other liquids that exceed it in solvent power in specific cases, no other shows such a wide range and general intensity of solvent power'.

You may well by now ask what is this to do with an energy conference? The answer is: everything. If no one wanted water you would not now need to collect it and pump it through pipes. In fact everybody wants it and no one can survive without it. This gives the water industry a high priority in the list of those who must have energy come hell or high water. Incidentally, one joker defined hell as a world in which oxygen was replaced with sulphur. Just imagine drinking H_2S instead of H_2O.

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* Chairman of the Watt Committee on Energy Limited

Water has other unique properties e.g. a density of one or to be more precise 1.000073 at 3.98°C. It has also a specific heat 15°C of 1.0. Furthermore, a gallon weighs precisely 10 lbs. These of course are man-made coincidences, but happy ones in that everyone knows what water is, and has a feel for it.

Turning now towards energy and the water industry, I presume your main requirement is for pumping, and that electricity or oil are the principal energy sources. In comparison with most industries your demands are small, whether taken in total or per ton of product. Furthermore, even our small hydro capacity would more than cover your needs, and the use of water for pumped storage will soon provide a major standby capacity for electricity. If we ever build the Severn barrage, water as a source of power in the United Kingdom would be quite substantially increased.

In addition to its role in power stations, both conventional and nuclear, it is essential to almost all industry. One of the outstanding examples is paper, which uses a large amount of low temperature heat mainly to get rid of the water from the slurry. One of the major problems in alternative energy processes, e.g. the biomass and recovery of oil from shale, is provision of water near to the chosen site. If hydrogen ever becomes a major alternative to gas or oil it will come from water, meantime, it is used as heavy water in most of the world's nuclear stations, and would be used as very heavy water (tritium based) if the fusion method of generating energy comes to our rescue in the next century.

Having supplied you with many reasons why water should have power and power should have water, I will try to summarize in a few pages "The National and International Energy Situation".

I do not personally expect a sudden and major drop in either oil or gas supplies, but such a situation cannot be ruled out. If it should happen we should have thought in advance of how we would deal with it. A Watt Committee on Energy working party has been studying this problem and come up with some preliminary answers. It has done so on the basis of three different scenarios one of which postulates a cut of 50% in the oil availability for UK consumption in 1985. For 1985 one could read 1980 or 2000 AD.

The energy resources of the World has been the subject of dozens of books and thousands of papers. The latest detailed statement is given in the five main reports of the 1977 World Energy Conference (1). These deal with coal, oil, gas, nuclear and renewables. Having reviewed all five volumes I am fairly familiar with their contents and the methods used in the estimations. I will not even attempt to summarize the numerous findings, but hope that the information given below will give a rough and for the present purpose adequate idea of what can be expected. As a first simplification it can be said that the UK position is similar in terms of expected resource duration to that of the World as a whole.

UK ENERGY RESOURCES

Coal

It has been stated for many years, and by people who should know, that the coal recoverable by existing methods, and consumed at exisiting rates would last about 300 years. In certain recent discussions much lower figures were suggested but it would seem that the difference is largely a matter of how one defines economically recoverable reserves. Even so it is important to appreciate how such reserves are calculated, and also how firm are the forecasts regarding supplies of natural gas, oil and uranium. Some clarification will we hope arise from the next meeting of The Watt Committee on Energy Consultative Council in December 2nd, 1980, when a number of people have agreed to present the position on energy resources. Meantime it is encouraging that oil exploration in the North Sea shows a lot of coal at depths of 600-3000 metres. It is not at present obvious how this can be tapped but it may well be achieved by our grandchildren, e.g. by using some variant of underground gasification.

Coal production is at present running at about 120 mtpa i.e. about half the rate achieved in the earlier part of the present century. According to the 1978 Green Paper on Energy Policy (2) a minimum of 170 t. was expected by 2000 AD, as a result of new mines such as Selby, and increased yields from existing pits. As will be seen later this figure has been replaced recently by a range of 137-155 mtpa.

The figures for the indigenous energy supplies in 2000 as quoted in the Green Paper (2) are shown in Table I.

TABLE I - Indigenous Energy Supplies - UK 2000 AD

Millions of tons of coal equivalent (MTCE)	
Coal	170
Nuclear and hydro	95
Natural gas	50-90
Indigenous oil	150
Renewable resources	10
Total	475-515

The distribution of resources has been well illustrated in a series of maps published in Report No. 4 of the Watt Committee on Energy Limited. These deal with:

Conservation and development constraints

Agricultural land quality

Fishing resources

Coal resources and development

Oil and gas resources and development

Oil and gas distribution and petrochemical location

Electrical power and generation transmission

Alternative energy resources

Alternative energy developments

They stress the importance of considering our heritage - aesthetic, agricultural and marine - when extending our search for all the main fuels, and also the heavy demands likely to be put on estuarial waters by mines, power stations, oil refineries and petrochemical installations.

In considering the need for more coal it should be noted that by 2000 this may well be the main fuel to replace oil and gas in power stations and boilers, and also the raw material for the production of gas and oil. Its application will be further extended by the development of fluidized bed combustion, which can make use of high ash, high sulphur coals without causing the pollution expected from pulverized fuel installations.

Oil

On several occasions this year I have asked audiences when they imagine North Sea oil to peak. At least twice I have been given the date indicated by the curves shown in the Green Paper viz 1985 - i.e. less than 5 years hence, but in general the question results in stony silence or dates nearer 2000. There is likely to be quite a lot of oil left by 2000 but the UK is expected to be a net importer but at what price? Long before then there will be strong "encouragement" to oil users to find other sources of energy.

Gas

Even North Sea gas is expected to last well beyond 2000 AD though its rate of production may well fall substantially. One very encouraging recent decision is to build a £3000 m pipe line to collect gas from the North Sea oil fields stretching from BP's Magnus field in the North to Fulmar in the South. It is suggested that this could add at least 1000 million cubic feet of gas to Britain's supplies in the mid 1980s - gas that would otherwise have been flared.

Both the Gas and Coal boards have been working for a long time on substitute natural gas of 1000 BTU/cu.ft quality, and seem confident that they will be able to build plants fast enough to maintain gas supplies as the North Sea output drops.

Nuclear

We were the first in the World with our Magnox reactors, and these have behaved admirably. We now run seven of them and in addition two Advanced Gas Reactors (AGR) of which we have more under construction. We have spent a lot of time considering whether we should also build American PWR (Pressurized Water Reactors), and have tentatively decided to proceed with one, subject to the approval of the design by the Nuclear Inspectorate. What happened at the Three Mile Island plant - also a PWR - though grossly exaggerated by the media has pointed out what we already know of any complex engineering operation, viz. that safety is in the end dependent on the human factor. The official view of the Nuclear Installations Inspectorate was that the accident was "largely the result of organizational and human failures compounded by some weakness in the design of the control room and its instruments". This is not the place to discuss the question of nuclear safety on which there remain widely different views. It would however be remiss not to touch on the other associated worry, viz. the disposal of nuclear waste. There is considerable interest in the development of one answer: the incorporation of the concentrated reaction phases in glass ingots. Just what would be done with these when they were made has yet to be decided but it was good to know that the government are taking the general question of waste disposal seriously - having recently allocated some £25 m for a year's research.

THE UK PRIMARY ENERGY BALANCE

Table II shown below has been reproduced by permission of the Department of Energy. It shows that even given a saving by conservation of 20% we shall be net importers of fuel in 2000 to the extent of about 100 mtce p.a. This assumes a major increase in energy demand - from 332 in 1977 to possibly 460 mtce in 2000. In the midst of a depression this seems unlikely, but we should not allow the present drop in demand e.g. electricity, to affect long term predictions.

TABLE II - UK Primary Energy Demand (Dept. of Energy data)

UK Primary Energy Balance			mtce
	1977	1990	2000
Demand			
Energy	332	370-390	400-460
Non-energy (inc. gas and bunkers)	28	40-45	45-55
TOTAL	360	410-435	445-510
Indigenous Supply			
Coal	122	127-138	137-155
Gas	60	68-71	62-65
Oil	65	153	100
Nuclear and Hydro	16	34-35	88-95
TOTAL	263	380-395	390-95
Net Fuel Imports	97	15-50	35-120

N.B. Figures do not add vertically

RENEWABLE ENERGY RESOURCES

The Green Paper on Energy Policy (2) only relies on a total for renewables of 10 mtce by 2000, but admits that given a major effort this might be increased to say 30-40 mtce. The major contributions to this bigger target come from waves (up to 15) and wind (up to 8 mtce). No one any longer doubts either that the energy is there to be got, or that means are not available to get it. What they can only find by testing prototypes is the cost of the power. The possibilities are set clearly in the last two maps in The Watt Committee on Energy Report No. 4 (3). These show for example that within a reasonable distance of Western Scotland and Northern Ireland the mean annual power available in the wave front is about 70 kW/metre. Few industrialized countries have such wave potential, and it is good to know that the Energy Thrift Support Unit (ETSU) are financing and co-ordinating a great deal of work in this field. Various designs are being considered. These include: oscillating vanes (or "ducks"),wave-contouring rafts, oscillating water columns, submerged ducts and flexible bags. The first named, often referred to as "Salter ducks", have already had preliminary and encouraging tests in storms on Loch Ness. Millions of pounds have already been spent on the preliminary studies, but we are still a long way from solving in detail the designs of the various types of energy converter or how they will be used to generate electricity. The wave-contouring raft was originally designed by Sir Christopher Cockerell.

Among the designs being considered abroad are the Kaimei ship recently on test in Tokyo Bay. This is a kind of ship-shaped floating egg box.

Anchored to face the waves it generates compressed air from rows of oscillating water columns in internal chambers. The air generates power by passing through a British made air turbine.

Geothermal power is still a good long term bet, and it is encouraging to read in August '80 that the Department of Energy have made a grant of £6 m to speed up this work on heat from the earth's core. Most of the grant will be administered by the Cambourne School of Mines in Cornwall. It is estimated that the equivalent of 6000 m tonnes of coal is available in the granite in the South West of England. A temperature of about 200°C is expected at a depth of 15000 ft.

Increasing interest is being shown in solar energy. Solar panels for water heating are becoming common in many countries having high sunshine levels. These are relatively simple in design and might well join the DIY industry. At the other extreme of sophistication should be mentioned the Solar Power Station (SPS) idea under development in the USA. The idea is basically a vast aerial equipped with thousands of silicon solar cells, the energy collected by these being beamed back to earth and captured over a relatively small land area.

Another wild, but by no means crazy, idea is the Industrial Island, i.e. an island set aside for industrial purposes. This could be natural but might well be artificially created at a convenient distance from the coast. Such artificial islands have already been built in Japan to provide land for steelworks and their auxiliaries. The idea is however far from new - after all much of Holland was under the sea. Such islands could be used in many ways, among them the harvesting of the energy of the sea-tides, waves, currents and thermal differences. They might also provide good sites for petrochemical and nuclear plant. It is suggested that they would mainly be built in shallow water - less than 60 m.

As a follow-up to a Department of Energy Report (4) on the prospects for generation of electricity from wind energy in the United Kingdom, a feasibility and design study has been made by a group of engineering concerns including British Aerospace Dynamics Group (5). They suggested a 60 m turbine diameter for the base case. Because the power output is proportional to the square of the turbine diameter a large turbine is desirable. It is thought that the design data would apply over the range 40-80 m, but any turbine over 60 m would involve fabrication of components whose size and nature were beyond existing practice. It is proposed that the turbine, gear-box and generator be mounted on a nacelle, turned to follow wind direction, and supported at 45 m hub height by either a reinforced concrete or steel lattice tower. It is estimated that the peak power output of 3.7 MW would be reached at a 22m/s wind speed. It is suggested that 150 such machines grouped in 3 areas could produce a fuel saving of 0.8 mtce.

Energy from the biomass has long been a reality, since most of the world's heating and cooking is at present done with wood. The contribution that can be made from special fuel crops, anaerobic digestion, fermentation to make fuel alcohol and other techniques was considered so important by The Watt Committee on Energy that they made it a basis of a Consultative Council teach-in in December 1978. The papers presented were so useful that it was decided to edit and publish them as Report No. 5 of The Watt Committee on Energy - entitled "Energy from the Biomass" (6). Considerable interest in the topic has been shown by good sales in both the UK and abroad of what we felt was a rather specialized approach that would be dismissed by many merely because all the biomass output with the population expected in

2000 AD would be needed to feed people.

WORLD ENERGY RESOURCES

Coal

The biggest resources appear to be in the USSR, China and the USA and their expected productions for 2000 AD are given in a new book: "Coal - Bridge to the Future" (7). These are given as 1100, 1450 and 1883 mt respectively. The magnitude of the world's coal resources and reserves is difficult to comprehend. Technically and economically recoverable reserves currently amount to 660 billion tce or approximately 250 times the world production in 1977. The world as a whole contains ample coal for the next hundred years but it must be noted that demand is bound to rise as populations increase and other fossil fuels become scarce. It seems likely that by 2000 coal may well become the transportable fuel instead of oil. New ships are already being built to meet the expanding demand, and oil companies are becoming increasingly interested in coal mines, and down-stream activities such as oil and gas from coal.

Oil

Half the non-communist reserves of oil lie in the Middle East. The heavy dependence of the rest of the world on this source was illustrated in 1973 when oil prices increased roughly four times virtually overnight; figures of about 2 dollars a barrel becoming 10-12. Since then they have risen to 25-30, and even 45 dollars for the spot market. The increases have had a profound influence on the industrial world even though largely political or religious in origin. The need to secure the future in countries whose main resource is oil will result in a tendency to keep more of the oil in the ground where it is safe from inflation. The obvious answer to those with little indigenous oil is to switch as rapidly as possible to other fuels such as coal, or oil and gas made from coal. A vast amount of work has been done in this field, but apart from Sasol (S. Africa) there are few plants of any size in operation. Vast sums of money have been set aside in the USA, but it is only now that the first demonstration plants are being built.

Other main sources that will doubtless prove economic as oil prices rise are oil shales, oil sands and bitumen crudes. Their development involves many problems, in particular their environmental impact. At its simplest this is that material removed in million ton lots for processing is unlikely to go back in the same hole after the oil has been extracted. In-situ removal is being considered, but here again the technical problems are numerous and as yet unsolved.

My own guess, bearing in mind the number of such plants that would have to be built and the long lead times, is that they will make little difference to the amount of oil available in 2000, but quite a lot in the period 2000-2025.

Gas

Because exploration has been concentrated on oil rather than gas and because gas supplies could be greatly augmented if all the gas flared at oil wells was collected, liquified, and delivered to world markets, it is likely that gas will be more generally available in 2000 AD than oil. To this comfort may be added the assurance of the Gas Boards that enough is now known about new ways of making 1000 BTU Gas from coal to enable SNG plants to be built to maintain supplies as natural sources run out.

Nuclear

The number of countries possessing nuclear power stations is continually increasing in spite of the protests of anti-nuclear lobbies, though earlier predictions of 10-15 fold expansion in the next twenty years, though technically feasible, are now thought to be on the high side. It is possible that Uranium ore might prove to be a bottle neck. Although there is plenty of Uranium in the world it would no longer be sense to extract it if the energy required exceeded that obtained when it was used in a nuclear reactor. Here the fast breeder reactor, as already installed at Dounreay, may come into its own for it can extract about fifty times as much energy from a pound of Ur as is obtained in an ordinary reactor. Furthermore it can be used to consume the waste that would otherwise be lost from conventional units.

Mention should be made too of the fission reactor - a prototype of which is being build at Culham, near Oxford. In this process an intensely hot plasma of hydrogen isotopes must be confined long enough for the nuclei to fuse together. The temperatures concerned, around 100,000,000°C, are somewhat in excess of the maximum melting point of refractories. The plasma must be prevented from touching the container and it is hoped to achieve this by means of strong magnetic fields. It seems unlikely that the first practical unit will be in operation before say 2025.

Renewable Energy Resources

Although the UK is well informed in this field and has considerable work in hand - see earlier section - it cannot be said to be leading the band except perhaps in wave power. Israel is probably making most use of solar heating, and the USA and Denmark are doing pioneer work in the field of wind generators. Brazil, which has traditionally operated its blast furnaces on charcoal made from eucalyptus trees, is now turning to ethyl alcohol made by fermenting unsold sugar as a major constituent in motor spirit. There has been a similar move in the USA to make alcohol from maize, and indeed this is now sold in a special blend called Gasohol. To be competitive it receives a government subsidy.

Geothermal heat has long been used in countries such as Iceland where volcanoes come near to the surface. More surprising is the fact that the district heating in parts of Paris is obtained by drilling on site. It has been reported that attempts to find oil in the Gulf of Mexico have periodically produced extremely hot brines, which contain large volumes of dissolved methane. It is said that if this could all be extracted there would be enough to supply all the US gas requirements. Large quantities of hot brine would however present both a thermal and chemical pollution problem. Pumped into the sea they might cause death to fish. Stored on land they would interfere with plant life, containing as they do not only a lot of sodium chloride, but salts of other metals.

Mention should also be made of tidal power. The La Rance project in France appears to be successful, and has not had the bad environmental impact predicted by its opponents. In the UK we have one of the five best barrage sites in the world, i.e. the Severn. This has been discussed almost as long as the Channel tunnel, but like the latter has scarcely passed the talking stage. Even if the latest commission recommends its construction it would probably take till 2000 to complete, and even then only supply a small fraction of the energy used in this country.

CONSERVATION - THE BIGGEST NEGATIVE SOURCE OF ENERGY

The word conservation means different things to different people. To the general public it generally means preservation of the environment in which we live; to the fuel technologist ways of conserving our energy supplies by more rational use. This latter aspect was dealt with at some length in Report No. 3 of The Watt Committee on Energy (8), which includes in addition to three papers on energy saving in houses, and house construction, others dealing with the health service, heat pumps, and furnaces. The final paper on instrumentation, motivation and human relations was the forerunner for Report No. 8 now in press. This is concerned with "Energy Education Requirements and Availability". It deals with the type and numbers of energy trained people likely to be demanded by industry in the near future, and the extent to which energy enters into courses given at Universities and Polytechnics. Two major points that emerge are that industry wants energy trained people, but because smaller firms cannot afford full time energy managers, they prefer short courses that will enable existing engineers or scientists to improve their knowledge of energy technology and particularly conservation techniques. To do the daily job of checking energy consumptions and reducing them they need trained technicians. This requirement will be studied by our Education Committee with particular reference to Technical colleges.

It would not be appropriate in the present paper to discuss, in any detail, the methods whereby energy can be saved by the water industry, or even any section of it. My long held and increasingly accepted view is that where little attention has been given to energy saving, be it in the home, commerce or industry, savings of up to 30% or over are often achievable. I break down this total under three sub-headings viz. good housekeeping, fuel technology and research and development. The first 10% could be achieved by many fuel technologists with their hands tied behind their backs. They would notice such things as steam and compressed air leaks, inadequate insulation, lack of proper draught control in merely touring a factory. To put these things right and achieve the next 10% necessitates not only common sense but technical knowledge and experience. Lots of people who know how such things as boilers are supposed to work would be at a loss to determine efficiencies or make the adjustments needed to achieve the saving. Even when the intended practice is obtained there can still be, what we called in our highly successful conference of British Flame Research Committee in September 1979, "The extra ten percent". This involves the use of advanced techniques as developed over the last 25 years at the International Research Foundation at Ijmiuden, Holland. Here the initial procedure is to ask basic questions, e.g. what are we really trying to do? Is this the right way to achieve it, and then make use of mathematical and aerodynamic models before building even a pilot burner or furnace. Many new concepts, e.g. the effect of burner thrust on heat transfer, and of swirl as a means of controlling temperature distribution have been developed and applied with major savings in many types of fuel burning equipment notably boilers, and furnaces. In giving the Second Saunders lecture (9) I gave the history of the IFRF, and listed a number of outstanding applications - leading in several cases to savings of millions of pounds.

ACKNOWLEDGEMENTS

If the present paper has been useful in highlighting the energy challenge of the next 20-25 years it will be largely due to the constant help I have received from many different groups and individuals. I cannot acknowledge them all, but would like to mention The Watt Committee on Energy, The Institute of Energy and last, but not least, The Department of Energy.

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DISCUSSION

Author's Introduction

Dr Chesters introduced his paper by pointing out the difference between reserves and resources. There was some confusion on this point, but the following illustration might make the distinction clearer. If someone had a bottle of whiskey in a cupboard at home, that was a reserve, which they could drink at any time. If, however, the whiskey was in a shop a few streets away, that was a resource, and to get to it they would have to go to the shop when it was open, and pay whatever price the owner asked.

Dr Chesters then showed and discussed slides of some of the maps from the Watt Committee's report no.4 (3). These showed the sites of present and future energy sources, and highlighted the restrictions which might be placed on their future development by environmental considerations.

(There was no further discussion on this paper)

2(a) WATER RESOURCES: SUPPLY, PUMPING AND DISTRIBUTION

C. Cash, BSc(Eng), FIMechE, FIWES*

INTRODUCTION

In the 7 years since the winter of 1973/4 the subject of energy has become one of the 'talking points' of our times and no doubt will remain topical for decades to come. The prospects of a growing world demand for energy against a background of eventual shortages compels our attention and we need urgently to consider ways of exploiting new sources of energy and how the energy we use may be conserved.

Electricity prices have risen by 150% in the last 7 years and more rapidly (by over 60%) than the average rate of inflation in the same period (1). This provides a clear indication of the impact of energy costs on our activities and the need for energy conservation measures. The days of cheap energy are gone and in the decades to come there are confident predictions that energy costs will continue to escalate. (A compounded 10% annual rise in electricity costs will double the price every 7 + years - a modest prediction on past performance.)

This paper sets out to examine possible areas for energy conservation in the water supply and distribution function. The energy potential at impounding reservoirs is examined together with the optimum use of water sources and energy within an integrated supply system. Electricity tariff structures are examined to identify where cost economies can be achieved, and methods of reducing the use and cost of electricity in pumping operations are reviewed including the benefits accruing from an efficient distribution system. Reference is made to the use of telemetry and computers in achieving overall objectives and also the role of management and staff in implementing an energy management policy.

RAW WATER MANAGEMENT AND ENERGY ECONOMY

Impounding Reservoirs and Water Transfers

Impounding reservoirs used either for river regulation or for direct water supply offer some of the more obvious opportunities for energy conservation measures through the development of hydropower. These reservoirs invariably involve releases of compensation water to protect the river regime downstream of the dam and much larger releases will occur if the reservoir is employed for river regulation purposes or if the river is used as part of an integrated resource system. This water may be passed through regulating valves at the dam which wastefully destroy the stored energy in the water.

Raw water for potable supply purposes is conveyed normally by pipe to the treatment plant and its energy is used either by connecting the reservoir head directly to the suction of pumps or to a turbine or possibly for providing a gravity flow through the treatment process to clear water storage. In cases where the raw water is released from the dam, perhaps into a river bed and abstracted at a lower point for treatment, the economics should be

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* Resources Manager, Bristol Waterworks Company.

examined of piping this water direct to the Works and providing on site generation.

There are many examples of hydropower schemes in the British Isles including some within the water industry. To quote examples, the North West Water Authority is operating a number of installations ranging from 40 to 150 kW capacity and the South West Water Authority also has similar sites of which the largest is 470 kW. Many of these installations have been in operation for 15-20 years. In most cases the amount of power generated is variable and depends on the availability of the natural resource and power surplus to the water authorities' requirements is exported to the grid. Escalating energy costs will provide the economic justification for more on site generation and the water industry should be aware of the possibilities.

Hydropower. Detailed examination of the engineering aspects of hydropower design may be found elsewhere (2) and the object of this paper is to draw the attention of the reader to this potential area of energy economy. Suffice it to say that the water turbine is flexible in use and very efficient over a wide range of operation up to the maximum discharge of the machine, but it is important to size the installation to give the greatest economic return on the investment. Fig. 1 indicates typical site power potential for a wide range of conditions.

Heat Pumps. A further possibility is the use of heat pumps to extract low grade energy from the water with the drive for the heat pump provided by the water turbine. This is a more efficient conversion of energy than the turbine - electric generator set, but the energy created is less flexible to use unless a specific need is located (e.g., space heating of buildings, chemical tanks etc.).

Exporting Power. The electricity industry is willing to co-operate in schemes where energy can be generated from natural resources and where technically feasible, they will consider purchasing at prices related to the industry's own marginal production costs. It must be kept in mind that if on site power is to be generated in parallel with a supply from the grid, the Electricity Board would need to make a separate 'standby' charge for that part of their supply which is required solely in the event of failure of the on site generation. It is important that water authorities take every opportunity to eliminate wasteful practices and to maximise the use of potential sources of energy in their own and the national interest.

Control of Integrated Source Systems

The amalgamation of Water Undertakings into larger units 15-20 years ago called for imaginative planning to meet rapidly growing consumption and many regional supply schemes were constructed during the 1960's and 70's with the resulting linking of sources over a wide area. The Regional Water Authorities have continued this progress towards complete integration of water supply networks because of the obvious advantages in system security and in the flexibility of operations.

Source Development and Yields. Water resources are developed progressively to meet growing demand using the local good quality waters first and moving further afield to the more expensive (and difficult to treat) sources as necessary. Sufficient source capacity must be available to meet long periods of dry weather and because of this under all other weather conditions surplus capacity is available not only in the source works but often in pipelines and reservoirs. This is a very important factor and immediately provides opportunities for resource optimisation in water, energy and other costs in all but the driest weather conditions.

Experiences at Bristol Waterworks Company. The flexibility of the supply and distribution system is such as to allow very large load transfers from one source or group of sources to another and it may be helpful to discuss the management of this system to illustrate what can be achieved by way of economies in energy and other resources.

The Company's sources consist of a mixture of groundwater (25%), surface water utilising impounding reservoirs (50%) and a major river abstraction (25%), the figures in brackets representing the percentages of total demand met by each source category under average rainfall/run-off conditions. Under '3 Dry Year' - 75% rainfall conditions these percentages will change to approximately (23%), (25%) and (52%) respectively.

All the major sources are priced for the variable cost elements (chemicals, power and part maintenance) and are used in priority order in accordance with a cost 'league' table. The variable costs of the river abstraction scheme is on average between 2½ and 3 times as expensive as other sources and was the most recent to be developed and, in fact, is the only source in dry weather conditions with surplus capacity to meet growing demand.

The hub of the control system is the storage in the impounding reservoirs and the policy is to use the ground and surface water sources progressively to full capacity according to yield, balancing demand from the river scheme. Control curves have been developed for the impounding reservoirs which allow these to fall sufficiently by the late autumn to prevent overflow of low (energy) cost water the following Spring in all but the wettest winters whilst at the same time preserving sufficient water to meet requirements during a 3 Dry Year period (worst condition).

A Sources Committee comprising Senior Management, Engineering and Operational interests meets just before the end of each month (to take full advantage of the power tariff periods) and abstraction rates and the associated least cost pumping strategy are fixed for the ensuing month utilising computer derived cost/Ml Tables. Marginal costs are also considered particularly in the winter months where the 'extra' water obtained by additional 'on-peak' pumping can be more expensive than taking water from the river source. Target and actual costs with variances are considered for each past month by the Committee.

Water from the groundwater sources surplus to local requirements is transferred out of the area where feasible to maximise their use and through a series of source transfers enables the abstraction of expensive river water to be reduced to a minimum.

The very large energy bill (fifth of total) from the river abstraction scheme has encouraged the Company to examine its pumping operations at this site. Having agreed the amounts to be abstracted from the impounding reservoirs, rezoning will proceed as required in order to place the correct demand on these sources and at the same time this will 'fix' the average monthly quantity to be abstracted from the river. Taking into account a complicated power tariff, available system storage, the head-volume and efficiency curves of the variable and fixed speed pumps in solo and parallel operation at the main 'despatch' pumping station and other design parameters, a least cost computer programme has been developed for each 2 Ml/day step of output over the operating range of the Treatment Works for use by the Station staff.

Conclusion. *Success in these operations will depend on the flexibility* available within the water supply and distribution network and some of the cost involved in the development of integrated systems perhaps originally on grounds of security, can be offset by extensive optimisation of resources including energy, water and chemicals at all times other than minimum yield conditions.

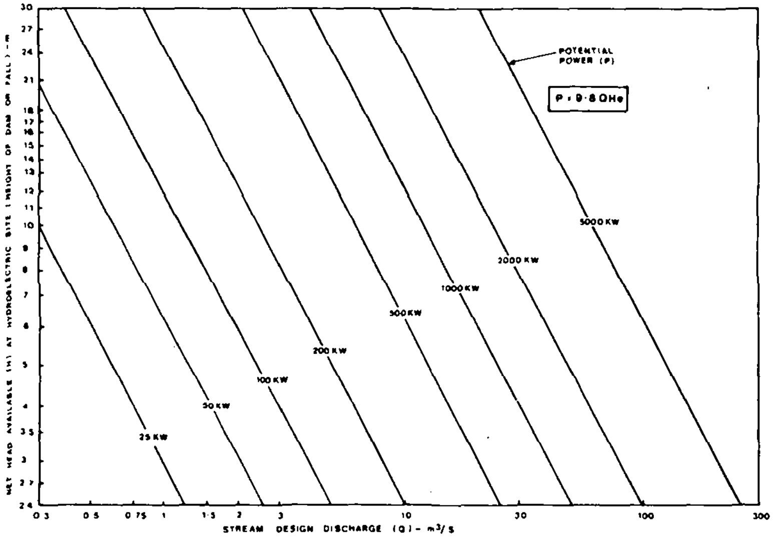

Figure 1 Hydroelectric Site Power Potential
Efficiency (e) assumed to be 0.85

THE ENERGY DRAIN

Evidence suggests that over 80% of the electrical energy consumed by most water authorities is for pumping operations and it is well worth analysing those aspects of pumping which affect energy use because this is where the major impact can be made in energy conservation:-

The energy used for pumping may)
be expressed by the following) $\text{kWhr} = 2.72 \dfrac{H \times V}{Ep \times Em}$
basic relationship:-)

Where the kWhr = the energy consumed, H = the average generated pumping head in Metres, V = the Volume of water pumped in Megalitres and Ep and Em are the pump and motor efficiencies respectively.

To reduce kWhr - 'H' and 'V' must be reduced and Ep/m must be increased as much as possible and the basic elements which can make this happen are summarised as follows:-

(1) 'H' - Pumping Head

(a) Reduction of static head by pumping to reservoirs at a level which provides adequate (but not surplus) pressure at consumers' premises.

(b) Reduction of friction head by optimum sizing of pumping mains (3) and the intelligent use of storage to avoid wide fluctuations in rate of pumping. (The most energy efficient pumping rate with respect to friction losses is the average flow rate to satisfy daily system demand.)

(2) 'V' - Volume of Water Pumped

(a) Reduction of volume by reduction of pressure in the distribution system to optimum value. This will reduce existing leakage in the mains and in consumers' premises. It will also reduce consumer consumption.

(b) Provision of more metered supplies (universal metering not justified at present for other reasons (4)).

(c) Water conservation by publicity and education and water authority initiatives to encourage design/use of water efficient appliances.

(3) Ep/m Efficiency of Pumpset

(a) Pump design and system operating conditions must be the same with pump operating at its peak efficiency point.

(b) Pump must not be oversized for duty even in early years of new scheme.

(c) Pump efficiency must be maintained throughout life of plant.

(d) Use highest efficiency motors for 'base load' duties.

(e) Consider choice and number of drives for best "overall" plant/system/tariff efficiency.

(4) kWhr - Energy Consumed

Implementation of the above will result in energy consumption falling to an optimum level and it only remains to exploit the available power tariffs in conjunction with (3)(e) above to obtain least cost operations.

This paper considers some of the above basic parameters in more detail though space does not allow a full study and where appropriate the subject is cross referenced to the appropriate source of information.

ELECTRICITY POWER TARIFFS

Virtually all pumping these days is carried out using power from the Electricity grid system. The Area Electricity Boards purchase power from the C.E.G.B. on the Bulk Supply Tariff and the Area Boards' tariffs reflect the charging structure and cost messages of this Tariff.

Because it is not possible to store electricity, the electricity industry spends vast capital sums in order to meet the instantaneous peak demands in the system and there is great cost incentive to minimise this peak and level out the use of electricity over the 24 hours. This is why the majority of industrial and commercial/domestic tariffs encourage the use of electricity during the evening/night period by offering energy at favourable rates (often less than half the cost of that purchased in peak periods).

The water industry with its ability to use reservoir storage for peak lopping, is able to take some advantage of this situation, particularly in the early years of new schemes where surplus pumping and reservoir capacity enables full or partial pumping operations to be shifted into the cheaper periods of the day. However, there are other opportunities where power tariff optimisation can be applied and some of these are discussed in the paper.

Tariffs and Trends

The Electricity Act does not allow the Area Boards to show undue preference in tariffs or terms to individual consumers, but it is well worth maintaining close links with the local Boards and particularly those responsible for tariff design since there is a willingness to consider special terms tailored to reflect the costs of particular "categories" of load. Some Boards also have standard "special terms" which may be available on request. It must always be borne in mind that failure to respond to any special terms (e.g., by load control) could mean that costs are higher than would have been the case on a normal tariff.

Generally, industrial tariffs have two main elements of charge, the first is for units (kWh), the second for demand (kW). The term Maximum Demand (MD) has become a household word in the water industry - and rightly so, because uncontrolled MD can result in unnecessarily high power bills and energy usage. The Boards' MD meter integrates (in kWs or kVA) connected loads over a 30 minute period and the maximum load in any half hour period during the month is charged at the rate applying in that month. Thus 100 kW connected for 15 in every 30 minutes of the measuring period will incur 50 kW or 100 kW if continuously connected for 30 minutes. The MD created often also affects the number of units charged at a higher rate so providing a further incentive to minimise MD. Some terms incorporating reduced charges for off peak usage measure the vital MD during the daytime only and it is this Demand which is used for determining the size of any unit blocks. In this case excess MD created in the off peak period is normally either charged at a low (summer) rate, or, in tariffs having a monthly service capacity charge, may be free of charge, and is not linked to unit block sizes. A typical standard monthly MD tariff with off-peak facilities is shown in Fig. 2.

Many tariffs now include the usual MD charge varying according to the month of the year in the usual way and a unit charge (or charges) which is not linked to the MD created. There is a lessening influence in recent years of the MD component of charge in the tariff due to the substantial rise in fuel costs which are reflected in adjustments to the unit charge. Recent special terms offered by some Boards have virtually dispensed with MD altogether and are based on a variable unit charge depending on the time of the day, the day of the week, and the month of the year. This latest development is very significant for the water industry since it allows a greater measure of flexibility of operation and does not penalise to the same extent as the traditional MD tariff. For example, emergency or inadvertent running of pumping equipment during the expensive winter daytime period for perhaps a few hours is paid for "by the hour" through the appropriate unit charge and not "by the month" through the monthly MD charge, and though the hourly charge is expensive, if used prudently, it is less onerous than the old MD tariffs.

Power and Load Factors

Power factor (P.F.) is the measure of the amount of current not converted to power in the total load connected to the supply. Motors and transformers both contain an inductive element which generates a lagging power factor and this becomes very apparent when either is operating at well below rated capacity.

The Electricity Boards penalise a low power factor because any excess current (amps) to that required if the plant were operating at near unity P.F. has to be generated and distributed to the consumer which is wasteful of system capacity. Some Boards charge if the P.F. is less than a particular level, usually 0.9 lagging whilst others measure MD in kVA rather than kW. (kVA and kW become of equal value if the power factor is 1.0.) Thus there is incentive to optimise power factor, by using capacitors to offset the inductive loads or synchronous machines, because then power costs are minimised.

Load factor expresses the relationship between units used and maximum demand incurred and is a measure of the number of hours plant is fully used in each (monthly) billing period. If a pump were operated continuously for the month, its load factor would be 100% with low average cost/unit. If a second pump of equal size were then operated for only 1 hour during the month, the combined load factor would drop to just over 50% and typically the energy cost in p/kWh would increase by 18% because of the MD penalty. In Fig. 2 the general effect of load factor on unit cost of electricity is clearly seen and the major exercise for the water industry is to minimise its critical MD loading and maximise load factor (and power factor) by every means possible to optimise power costs.

Relationship between Energy and Cost

Finally, it must be recognised that heavy off peak pumping at high flow rates may cost less but will use more energy in a given period because of increased pipeline friction losses. When looked at within the water authority this seems surprising, but in the wider context after allowing for the extra electricity generation and distribution capacity that would be required (with its capital/energy content) if no attempt were made to reduce the peak period demand the overall use of energy by the C.E.G.B. is optimised. In the ultimate the cost of the product is the key factor and provided that electricity charges are cost reflective, the water industry must assume that in optimising its costs, total energy consumption is also optimised on a national basis.

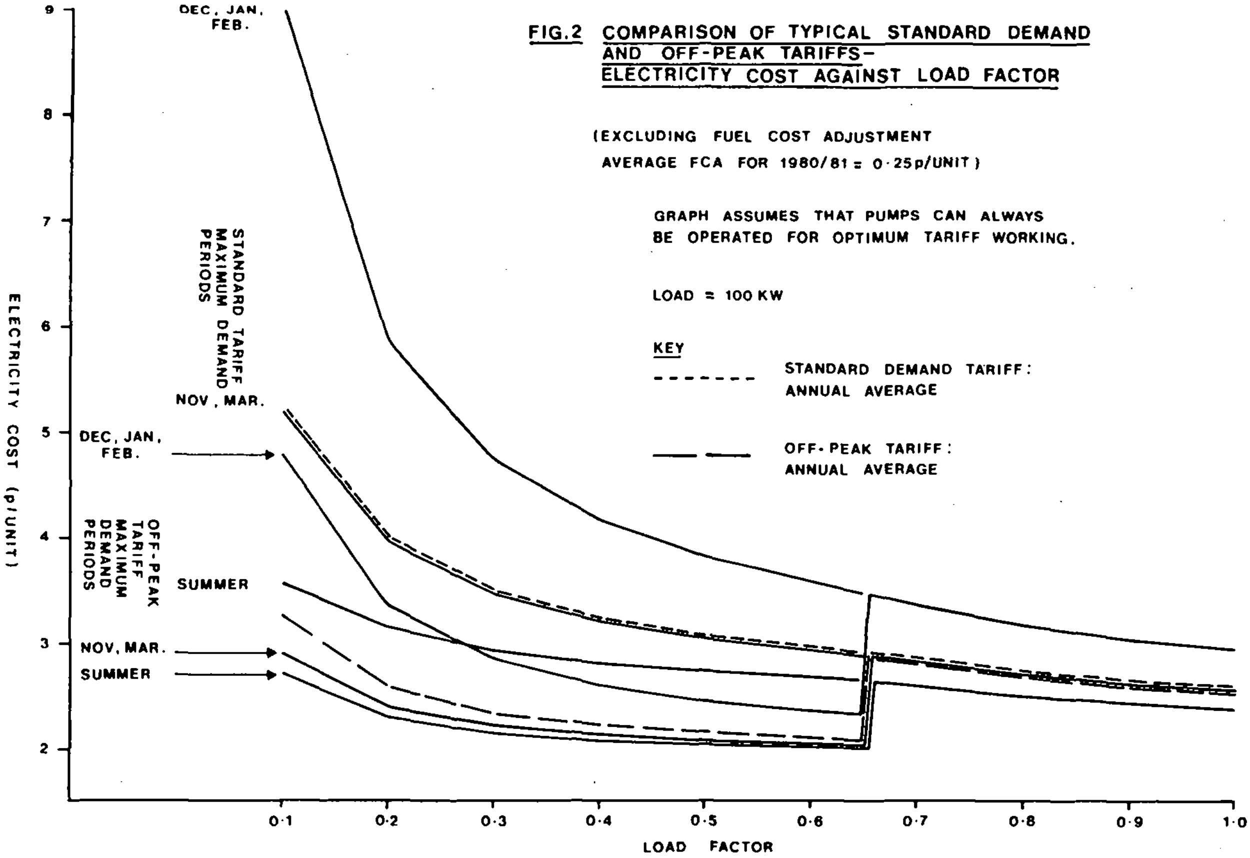

FIG.2 COMPARISON OF TYPICAL STANDARD DEMAND AND OFF-PEAK TARIFFS– ELECTRICITY COST AGAINST LOAD FACTOR

(EXCLUDING FUEL COST ADJUSTMENT
AVERAGE FCA FOR 1980/81 = 0·25p/UNIT)

GRAPH ASSUMES THAT PUMPS CAN ALWAYS BE OPERATED FOR OPTIMUM TARIFF WORKING.

LOAD = 100 KW

KEY

- - - - - - - STANDARD DEMAND TARIFF: ANNUAL AVERAGE

—— —— OFF-PEAK TARIFF: ANNUAL AVERAGE

DESIGN/OPERATING CRITERIA IN PUMPING INSTALLATIONS FOR OPTIMUM USE OF ENERGY

Pumping Specification for New Plant

As much information as possible must be given to the Tenderer about the basic scheme and its requirements, the estimated growth of demand where applicable, the suggested pumping configuration and way pumps are to be used to make the best use of power tariffs and storage facilities. Include information about tariffs and the average unit cost of electricity with some allowance for the inevitable rise in energy costs over the life expectancy of the plant. The pump manufacturer can then establish the likely periods of operation at each particular pumping duty. Some freedom should be given to encourage alternative offer(s) which may prove to be better in overall energy terms.

The specification must request information about plant operating efficiencies as well as the capital cost and award the contract on the basis of total annual charges (capital and operating) because by so doing the manufacturer must consider operating costs including the best efficiency of motors and pumps. Furthermore, if he is providing a 'package station' he will also be encouraged to keep other station losses affecting energy consumption and therefore operating costs to a minimum (e.g. station pipework and valves, cabling, power factor correction etc.).

Consideration must be given to all aspects of station design where energy can be wasted and a few examples are quoted below:-

Pipework and valves must be of optimum size (capital charge and friction los costs p.a. must be optimised) and avoiding sharp edges, all changes of direction achieved by smooth full radius bends if practicable. Choose internal pipe lining with good friction properties and long serviceability. Include energy loss considerations when reviewing the available ranges of valves and flow meters.

It is worth remembering that approximately 5 kWhrs (units) are consumed per megalitre metre in pumping operations. Thus losing 1 metre of friction head in passing 1 megalitre through station pipework continuously at 2.75 pence/unit will cost approximately £1,200 every year. The correct design of pump suction chambers (5) is also important and can affect pump efficiency and energy losses.

Pumps. With tender adjudication taking account of plant efficiency, the manufacturer can offer the best overall performance for solo and parallel operation. If the range of pumping duties is wide, make sure that good efficiency is achieved over the whole range with the best efficiency at the most frequent duty point. Do not over-size pumps or be pessimistic about system friction losses and consider how a high load factor can be achieved during the early years of operation. Many stations are required to operate at a poor load factor or outside the peak efficiency point of the pump as a result of the engineer allowing "margins of safety" at each stage in the design. Sometimes too, a distribution zone is modified without thought to the effect this will have on energy efficiency at the pumping station.

Consider variable speed drives which allow peak efficiency to be followed over a wide range of pump duties (see v.s. motors). If the pump is fitted with glands, consider using pump seals which are efficient and virtually frictionless and watertight. Remember that pumps fitted with thrust bearings absorb extra energy and waste water if the bearing has to be cooled. (40 litres/minute lost in cooling water in a pump represents 21 Ml/annum and would cost approx. £500 p.a. to replace from Bristol's most expensive source.)

Whilst pump efficiency is important when the pump is purchased the ability to sustain a high performance for a number of years is crucial. (See page 12). The manufacturer is interested in the acceptance test and he has the benefit of brand new parts, surfaces, clearances, etc. The wear, tear and roughness on a pump in continuous operation over many years' operation particularly handling raw water can badly affect performance. What can be done to improve long term performance? Is this an area which might be investigated with advantage by the appropriate research body working closely with the manufacturers?

Electric Motors. There is likely to be a clear advantage in using highest efficiency motors in high load factor pumping applications and the pump manufacturer is well aware of the situation. (Machines operating intermittently, e.g., some treatment works' drives may not justify the extra cost but a total annual cost exercise will prove the case.) Unlike the pump, the motor remains very efficient over a wide range of duty (half F.L. to Full Load), however the power factor can be badly affected falling typically from 0.9 to 0.75. This has to be carefully monitored and capacitors (or similar) installed to maintain p.f. at a level which does not attract tariff penalty charges. It is normal to allow a 10% margin of power in the motor sizing over the design duty in case over-size impellers are needed in the pump, but this will not adversely affect energy efficiency.

The variable speed motor for pump drives is well worth considering in the energy context. The A.C. commutator motor is not so efficient as the fixed speed induction motor (there is a loss of about 5% in motor efficiency, size for size). The variable speed drive is potentially of great importance as a means of cutting energy and costs. Some of the advantages and disadvantages are tabulated in Table I as follows:-

TABLE I - The Variable Speed Pump Drive

Advantages	Disadvantages
1. Variable pump output enables system water pressure to be optimised in closed boosted zones with savings in power and water.	1. Higher initial cost than standard industrial F.S. motors/controls.
2. Enables high pump efficiency to be maintained over a wide range of pump duties where this is required.(6)	2. Some loss of operating efficiency when using commutator motor.
3. Sometimes avoids the need for multiple fixed speed pumpsets with economy of building and other costs.	3. Equipment is more complicated than fixed speed drives and is therefore subject to increased maintenance costs.
4. Enables power tariffs, service reservoir capacity, pipeline pressures and pumpset efficiency considerations to be combined and optimised, utilising computer (micro processor) package.	
5. Some reduction in requirements for surge protection.	

In recent years variable frequency inverter speed controls have become available for use with standard squirrel cage induction motors up to approximately 150 BHP above which the drives become very expensive. These are very useful and flexible devices and enable the speed of installed submersible pump motors as well as other pump drives to be varied though it is advisable to consult with the local Electricity Board before fitting the devices as they can cause interference on the Boards' network under certain conditions.

Existing Pumping Installations

It is suggested that the following 'energy' check list might be applied to existing pumping equipment in addition to the points discussed under 'new plant' as follows:-

(a) Is the pump operating at its best efficiency point? (Preliminary check utilising station instruments and pump works test curves.)

(b) Check the amount of friction present in the pumping main and calculate the C value and annual power consumed by friction losses. Is there a case for main scraping and lining or partial main duplication?

(c) From the Electricity account, what is the station load factor. Aim for 60% + (see Fig. 2.) Consider reduction of impeller size and/or fitting of different size impellers to suit summer and winter duties. Will motor efficiency be adversely affected? Consider changing pumps if grossly over-sized for duty.

If several motors (or other loads such as heaters, cookers, etc.) are operating intermittently and supplied through a single power meter, consider how these loads can be interlocked for planned running to reduce Maximum Demand and improve load factor.

(d) Is the station operating under the best power tariff? Carefully consider the alternatives including partial off peak operation.

(e) Is the best use being made of reservoir storage in relation to the tariff? As a guideline maintain sufficient daytime storage to cover burst main repairs (12 hours is reasonable) and use the remaining storage to meet peak consumption and to optimise the tariff. It is wasteful to have a power tariff with cheap night units between 0100 and 0600 hours if the reservoir is filled by 0200. Programme the pump controls to lower the reservoir water level during the evening (possibly to a lower point than would be acceptable during the daytime peak demand) to ensure maximum pumping over the full period of the cheap units. A suitable application for a microprocessor perhaps?

(f) If power factor is relevant, check reading and correct to appropriate value by fitting capacitors in accordance with acceptable practice. (Do not forget the effect of transformer inductance.) If MD is measured in kVA consider automatic capacitor controls to achieve near unity power factor.

(g) Consider connecting variable speed control to one or more pumps to optimise the power tariff and/or water pressure values.

(h) Check actual pumpset efficiency with Works Test performance. Overhaul and retest as necessary (see next heading).

(j) If several transformers are provided at the station - consider disconnecting those on standby duty but aim to rotate at regular intervals. (Discuss proposals with the manufacturer first.)

Site Efficiency Testing and Maintenance of Pumping Plant

The ability to sustain a high level of pump efficiency throughout the operating life of pumps (and motors) is equally, if not more important, than securing the manufacturer's guaranteed performance on the acceptance trial for pumping machinery. The cost of energy is such as to make a significant difference to the power bill if plant is down on efficiency. The following Table II illustrates this point and (a) shows the effect of a 1% drop in pump efficiency at varying Horse Powers whilst (b) records typical losses in efficiency on pumps in service.

TABLE II - The effect of loss of plant efficiency on operating costs

(a)

BHP of Driving Motor	Effect of a 1% loss in pump Effcy. at 75% load factor		Remarks
	Wasted Units per annum	Extra Cost per annum	
100	3750	£150	Note: A 2 kW fire energised continuously for 1 year consumes 17500 units
250	9700	£350	
500	20500	£650	

(b)

Pump Duty Qty. x Head (Ml/d) (m)	Driving Motor (BHP)	No. of Years since overhaul	Reduction in overall Effcy. (%)	Avg.Addl. Cost (£) per annum	Water Quality
27 x 102	525	11	8	5780	Raw
4.5 x 105	97	10	6	750	Potable
2.5 x 81	40	15+	12	630	Potable

The difficulty is to identify the fall in pump efficiency because it is progressive and occurs imperceptively. It is suggested that the best method is to obtain (sub-standard) test bed equipment to measure the power input to the motor terminals and pressure change across the pump flanges. Accurate site flow measurement remains a problem and without direct measurement facilities it is suggested that the calibration curve for the primary flow element is used in conjunction with a manometer to obtain acceptable results. If this is repeated annually until the efficiency trend is established, it should then be possible to optimise the frequency of overhaul. The cost of a major overhaul on a 500/600 HP multi-stage pumpset can be as high as £8/9000 excluding major replacements and over-maintenance should be avoided.

Some progress has been made in the development of an alternative much simpler method of site testing of pumps which does not utilise flow measurement (an advantage) but measures temperature and pressure rise across the pump flanges. It is assumed that the energy (efficiency) lost through the pump is dissipated as heat to the water thus creating a very small temperature gradient which is detected by a sensitive thermo couple.

A good plan is to tackle the largest installations first, perhaps all those above 200 BHP and of these priority should be given to installations handling raw water or waters known to have abrasive material in suspension.

THE DISTRIBUTION SYSTEM

Energy economy within the distribution system is dependent on a number of considerations and those aspects affecting energy consumption are examined below.

Attention is drawn to the Report (7) on 'Control of Leakage' issued jointly by the Department of the Environment and the National Water Council which is relevant to some of the following subjects:-

Optimum Pressure Conditions

The first requirement is to see that water reaches the consumers' premises at the correct pressure. Excessive pressure inevitably involves wasted energy not only in lifting water to too high a level, but also in the extra leakage that will occur from the system. Excessive pressure may be the cause of the largest single waste of energy in the distribution system.

This suggests that reservoirs must be constructed at the right level and that only the water needed at the higher levels, e.g., over hillsides and hilltops should be lifted to those levels progressively utilising one or more relift pumping stations. This seems obvious, but in practice is often not achieved for a variety of reasons. The simplest water supply system is that containing one reservoir constructed at the highest point to which all water is pumped with all consumers supplied from it and utilising PRV's and break pressure tanks for those parts where the pressure is too great. Simple to operate, few complications, but very wasteful of energy. Having said this there is little doubt that very large numbers of consumers in the country receive water at too high a pressure.

In most distribution systems pressure will range from 15 to 100 metres + and yet a service pressure of 30-35 metres is more than adequate for most situations. It is not considered necessary to provide additional pressure for high rise flats and other tall buildings the responsibility for this resting with the owner. It would be wrong therefore to justify higher zonal pressure because of problems with tall buildings.

Very often in a large zone there is a wide range of pressure within the zone itself due to the general disposition of reservoirs, ground contours and constraints within the pipe reticulation. It is impossible to generalise too far, but each system is worth close examination to see if capital in reservoir storage or improvements in pipework can be justified on economic grounds. (Remember that energy costs are rising faster than inflation and that there will be economy not only in the direct saving of pumping head but also in water conservation.)

The Planners. Looking ahead as energy costs continue to rise, is it reasonable to suggest that the planning authorities include 'energy' as a consideration in the long term structure plans to test the feasibility of confining housing development to the lower contours of land and thus avoid pumping energy.

Water Conservation

As indicated earlier a direct and proportionate reduction in energy charges is achieved by by reducing water consumption either by tackling leakage and unaccounted for water or as a result of consumer economy. Additional benefits (other than energy) will follow including a reduction in water supply, treatment and recovery costs and this combined prize is worthy of close attention.

Conservation through Pressure Reduction. It is recognised that pressure reduction will reduce leakage in the system. About 20% of distributed water is lost through waste and as most distribution systems at some point operate at too high a pressure the opportunities for energy/resource economy are considerable. There is some difference of opinion on how the flow of 'waste' water will vary with changes in system pressure. Ridley (7) on Leakage Control (page 35-6) suggests that the relationship obtained from trials is shown by the solid line in Fig. 3 which means that for quite small reductions in high pressures a correspondingly greater reduction in leakage will occur.

This is the converse of the theoretical square root relationship between the flow through an orifice and the pressure (shown dotted) which was previously thought to apply to overall leakage levels and it is interesting to record that as recently as June 1980 the American Waterworks Association published a compendium of papers on Energy Efficiency where Patton and Horsley (8) firmly supports the square root theory.

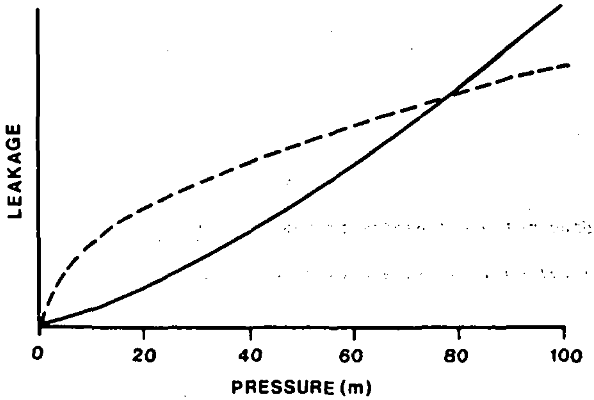

Figure 3 The effect of pressure on leakage levels

The important point is that when pressure is substantially reduced there is also a worthwhile reduction in 'leakage' water. If direct pumping occurs into the zone then there will be an energy saving at the pumping station in direct proportion to the reduction in pressure but if pressure reductions are achieved by the use of PRV's then the energy saving is limited to the economy in wasted water, also any resulting economy in residential use. If waste is 20% of the water consumed and a 30% economy is achieved through pressure reduction then the waste of water will reduce to 14% with direct energy savings at the primary pumping station and reflected savings at the secondary pumping, treatment and source works.

One has to accept that the figures quoted are indicative only of the potential savings and it is hoped that actual cases of economy will be quoted by Water Authorities and Companies during the discussion and reference made also to any possible undesirable side effects as a direct result of pressure reduction measures.

Some work on pressure control has been undertaken at Bristol and this will continue but results on three independently operated systems may be of interest. (Data on third zone to follow.)

The first two zones are supplied by continuously running pumps, one a small rural and the other a larger urban area. The third involves a gravity fed system with relatively high pressure. In the first two trials there is no storage available and the pumps are conventional centrifugal sets.

Pressure varies with demand in accordance with the head/volume characteristic curves of the pumps. Experiments have established that notable savings can be achieved by operating these pumps with variable speed drives to maintain the output pressure constant. The zonal pressure is reduced to a minimum value which is compatible with consumer demand during peak periods. The pump speed control can be further refined by dropping pressure to a lower level at periods when a small demand is expected on the system (e.g. at night and at low consumption periods in the day but an override can be put into the circuit if an unusually high flow condition occurs in periods of normally low consumption). The results of the test are shown in Table III.

TABLE III - Pressure/speed reduction tests for "pumped" zones

	RURAL ZONE	URBAN ZONE
Range of operating pressure (M) for original Fixed Speed installation	34.5 - 30m	33.5 - 24.5
Operating pressure (M) for modified variable speed pump	24.5m	24.5m
Daily Quantity Pumped (Ml)	0.26 Ml/d	5.5 Ml/d
Average Pressure Reduction (%)	25%	15%
Zonal Water saving %	14%	6%
Power saving £/pa (primary pumping station)	£170 (23%)	£1200 (18%)
Other savings (energy and chemicals etc through supply system) £/p.a.	£290 (9%)	£3000

Conversion to variable speed drive in each case is achieved by fitting a variable frequency inverter (thyristor) into the supply of the existing fixed speed motor.

Care needs to be taken in interpreting results however as conditions will vary from one area to another but it is inevitable that some economy of water will always be achieved when system pressure is reduced.

Reference has been made to the need to optimise pressure in the original planning of reservoirs and pipe networks. In zones where this cannot be achieved without excessive cost the PRV is acceptable on grounds of water/overall energy economy although the device is wasteful of energy. Refinements enable these valves to be automatically adjusted from a remote point (e.g., a pressure transducer mounted at the critical pressure point in the zone). The third trial in progress utilises a PRV in a gravity fed zone consisting of urban housing development with a daily consumption of 1 Ml. Water is supplied from a command reservoir at a pressure of 80 metres which was progressively reduced over a period of weeks utilising a PRV and the daily flow recorded at each pressure setting. A comprehensive picture of the variations in consumption and waste is being prepared and the information is to be applied to Companywide data on zone pressures to assess potential savings and establish priorities in a programme of pressure optimisation. Results to date will be made available at the meeting.

Conservation through Metering. This subject has received a good deal of attention in recent years and there is a general acceptance that universal metering is not justified at present on economic grounds though some groups of consumers are being offered the alternative of being charged for water by meter. Historical data suggests a long term economy of about 5% if domestic consumers are metered (4).

Waste Detection. Waste of water both by the public/industry and within the water system is another important factor having a direct energy link. There is certainly no merit in expending energy in treating and pumping water which the consumer never sees because it is lost to the system. The subject of leakage control has always demanded and received a good deal of attention with every justification but never was this more appropriate in a period of steeply rising energy costs.

Ridley (7) on Leakage Control provides us with a wide-ranging and workmanlike document and a point of reference for the continuing improvement and refinement of cost effective waste control measures.

Comprehensive arrangements are necessary for the detection and measurement of waste including not only the well established waste districts, but also the water lost in reservoirs, trunk and leading mains. Computer based telemetry can play an important role in the early detection of abnormal conditions (burst mains and the large leaks). The cost of waste control measures must be related and optimised to the cost of the water which would otherwise be lost, also the delayed capital expenditure in developing new schemes no longer required so soon. It is recommended that the variable water costs (energy + chemicals) is made available in each waste district/zone as a consideration in setting work priorities for the waste/repair teams. The "listening stick" has done stalwart service over the years (and will continue to do so) but other devices are coming on the market to locate leakage more precisely including the "Leak Noise Correlator" developed by the W.R.C. the first results from which are encouraging.

Consumer contribution in Waste Control. It is an enigma that water authorities are prepared to invest considerable time and money on waste prevention/energy economy measures and yet have little or no influence on the way consumers use this precious resource except in times of scarcity. The metered consumer whose consumption is directly linked to payments is the one group who is likely to be less profligate with the commodity.

In his Presidential address, Mr. Lowther referred to the 'haves and have nots' of this world and the need to use our resources prudently to help those in less fortunate circumstances. In the context of energy resources this was never more apt and I suggest that the water industry should no longer be prepared to take a relatively passive role in its relationship with consumers and their water needs.

The 1975/6 drought clearly shows what can be achieved by publicity and exhortation during a water shortage. Consumption was reduced by at least 15% and yet in the last two years consumption has been rising in some areas at a rate of 4% per annum. Is it not reasonable to consider a nationally led publicity campaign (using the best available publicity consultants) to bring the public and all interested parties into partnership with the water industry to fight waste and preserve this precious water resource and the energy used in treating and pumping it to the consumer? The Gas and Electricity industries regularly use the media to advance their own sales policies (geared very often nowadays to energy thrift) and why does the water industry not use the same methods to educate the public (and associated appliance suppliers) towards a more responsible attitude in the use of water. The results of the publicity campaign may well prove to be as effective as the water authorities' own efforts to conserve water and the hoped for economy will surely justify the expenditure.

Telemetry as an aid to energy economy. Computer based telemetry can play a useful role in energy economy and many of the potential savings discussed already can be more readily achieved by its use. Recent papers on the subject (9, 10, 11) refer in some detail to the potential benefits and because of space only those aspects having a significant influence on energy consumption and costs are listed as follows:-

(a) Ability to continuously monitor pressure in distribution systems from the Operations Centre to minimise waste caused by excessive pressure and to control and vary pressure limits according to demand.

(b) Provide accurate data on diurnal variations in reservoir storage, consumption, flows and pressures in distribution zones to identify suspect high leakage areas and to provide early warning of burst mains and other serious leakage.

(c) To optimise the operation of pumping plant and utilisation of sources by monitoring reservoir storage taking due account of integrated supplies, demand patterns and power tariffs.

(d) Ability to monitor the operation of pumping installations to detect and cancel unscheduled use of pumps with subsequent economy of power costs.

(e) The accurate monitoring of the distribution network, pumps, reservoirs, pressures and flows provides more information about the water system which in consequence can be used more flexibly with deferment of capital (and energy) expenditure on New Works.

OTHER DAY TO DAY OPERATIONAL ASPECTS

Building Services

Heating and Lighting. This generally does not represent a large energy commitment except in the major offices (e.g., Authority/Divisional H.Q.). The latest office blocks are designed having integrated services for energy economy and need no further comment here. Specialist consultancy services are available and there is merit in making use of these leaving the water engineer to get on with his specialisation. A few general points may be helpful as follows:-

On Lighting

(a) Examine light fittings and consider changing for high efficiency (low energy use) units. This applies equally to fluorescent tubes as well as other forms of lamp. The latest high pressure sodium lamps use only a quarter of the power needed by conventional lamps for the same light output. These lamps also have a longer life and run cooler. It is suggested that the tungsten lamp used for lighting large areas for lengthy periods is a thing of the past.

(b) Consider sectionalising lighting controls and switching locally. This allows areas away from windows to be switched independently from those nearer a source of daylight.

(c) Consider the use of photo electric cells and other devices to disconnect lighting when it is not required.

(d) Operate routine maintenance to sustain efficiency.

(e) Encourage staff co-operation through training/publicity. Experience shows there is a need for lighting discipline.

On Space Heating

(a) Consider the choice of fuels. The practicality and convenience of various fuels plays a large role in the choice of fuel. There is no doubt that electricity has advantage at small unattended stations even though it may not be the least expensive fuel. National strategy suggests the use of gas for the space heating of large buildings.

(b) Unmanned pumping installations. It is normal to use electric heating under thermostat control sealed to prevent tampering and set to 40-50°F. Consider interlocking the heating with pump motors to improve load factor. Maintenance staff can be provided with portable (gas) heaters for personal use when working at unattended stations.

(c) Manned (Treatment) Works can present a heating problem because of their size and the simple fact that staff require higher temperatures than most plant. There is virtue in providing a permanently screened off area in the vicinity of the Control/ Monitoring Centre for staff to avoid heating the whole building to a high level.

(d) Building insulation. New buildings must be designed with a high level of insulation with adequate ventilation and the use of sophisticated heating controllers may be worthwhile even for quite small installations set to avoid critical condensation conditions and to optimise energy use.

(e) Men working in the open returning to Depots possibly cold and wet require "instant" heat and consider the use of bottled gas blowers or similar devices, but avoid heating buildings all day for occasional use.

Treatment Works

There is scope for energy/cost reductions in the operation of treatment plant and although the subject is to be considered in detail elsewhere, it might be helpful to review the more obvious aspects:-

It is unlikely that a treatment plant will not contain an element of pumping to handle the main flow of water into and away from the works. In the early years of a major new scheme there is usually sufficient pumping, pipeline and storage capacity to permit a considerable measure of off peak pumping with consequent energy/cost savings. The treatment plant will normally require steady operating conditions with occasional changes in flow rate through the works and computer optimisation will enable least cost operations to be obtained from the power tariff.

Further economies can be made by arranging for filter washing to be carried out at night when energy is cheaper and this principle could apply to other operations where items of plant are used intermittently.

Where plant has to be used during the (expensive) daytime period of the tariff though not necessarily continuously, consider how the various loads may be interlocked to improve overall load factor.

Consider recycling waste water.

Process automation (e.g. filter washing, chemical dosing etc.) is likely to be more efficient in energy use than manual operations - therefore consider feasibility of applying automatic controls.

Regularly check water, air, oil and chemical lines for leakage.

Transport

Fuel oil for transport and mobile plant represents a significant element of a water authority's total energy bill (about 10% at the Bristol Waterworks Company) and therefore justifies close examination.

To conserve fuel in transport operations attention must be given particularly to the following four factors:-

(a) The vehicle must be kept in good condition through preventative maintenance. Consider more frequent use (perhaps every 5000 miles) of electronic tuning for precise engine performance. One Public Authority reports that this has proved more beneficial in achieving fuel economy than most of the "bolt-on" devices or fuel additives available on the market. Other aspects of maintenance affecting fuel consumption are - correct tyre pressures, correctly aligned front wheels and brakes free from binding.

Transport facilities should be such as to allow all the foregoing items to be carried out at the desired frequencies. It is important for the Transport Manager to keep abreast of developments in alternative fuels e.g: LPG, battery power etc. and to be prepared to experiment.

(b) The driver's contribution to fuel saving can be very significant and to get him involved and enthusiastic is difficult but worthwhile.

Publicity and training are essential with emphasis on the importance of good driving habits. Provide aids in the cab for drivers' reference. In the local training sessions ask for ideas on how fuel might be saved - it is surprising what may be offered and from it the staff involvement grows. Consider the use of perspex stickers in appropriate vehicles for fixing to the speedometer to provide a guide to the driver of the maximum speed to be used for economy in each of the gears.

(c) Journey Planning would seem to be an obvious option to follow but in practice it is not always easy to achieve. Much of the success of this will depend on the driver's and supervisor's abilities in organising journeys and work schedules. Discuss the problems and identify weaknesses in current operations. Make changes where appropriate. Consider extending the use of radio communications in vehicles to help avoid unnecessary journeys. Ensure that vehicles are not carrying unwanted material thereby wasting fuel.

Is there vehicle overmanning of the site?

(d) Monitoring and Control of fuel consumption and mileage is an essential pre-requisite to a successful energy policy. The quality of the base data is important and statistical analysis may be achieved through the computer with regular presentation of data in any desired form (by Depot, vehicle, type of vehicle, vehicle function etc.). Once established consider setting performance targets for Depots, individual drivers etc., but first ensure that regular data on performance is available for the staff.

SOME GENERAL THOUGHTS ON ORGANISATION

This paper has highlighted some of the areas suitable for energy efficiency in the water supply, pumping and distribution function. It is important also to consider the planning and organisational aspects required to implement a successful energy policy.

The key to success is to ensure a genuine commitment from Senior Management and if the necessary priorities and resources are lacking, the energy drive will sink without trace. The appointment of an Energy Manager, either full or part time depending on the size of the authority, is of equal importance and his duties must be well defined (for the benefit of all) with the appointee having direct access to, and the support of, senior staff. In the larger authorities, the Energy Manager will need to work closely with staff in the various divisions nominated and responsible for implementing energy policy. Consider forming a working party to implement policy, discuss progress, share problems and ideas etc.

One of the first tasks is to establish the correct flow of information for energy audit purposes. This must include details of energy consumptions and other statistics to show how and where energy is being used. The audit can reduce substantially the cost of energy by the following:-

(a) preventing over-payment of accounts;

(b) providing a true picture of energy consumption;

(c) detecting trends in consumption;

(d) evaluating alternative tariffs;

(e) evaluating the effectiveness of fuel saving measures;

(f) comparing actual consumption with previous periods and with performance at other plant, premises or supply zones;

(g) monitoring energy performance and providing consumption target figures for all premises (plant and buildings);

(h) estimating cost implications when price rises occur;

(i) highlighting areas of high consumption both in energy and water and suggesting strategies for energy saving;

(j) feed back information for design of new installations;

(k) measuring the overall performance of the authority's energy saving policy;

(l) measuring the performance of energy control measures by quantifying savings and confirming that investment was justified.

The development of information systems for monitoring energy use will almost certainly require an extension of on site measuring devices and once available, the total information must be collated and processed for re-presentation and analysis. This is a considerable task and can best be done using a computer and logically the telemetry system may well be the most appropriate work-horse with much of the information arriving routinely for computer processing and the remainder fed in from monthly site visits via the keyboard.

The Energy Manager will have other responsibilities and will be required to:-

(a) Initiate investigations into energy wastage and new equipment/ routines for better energy performance (most enquiries directly as a result of the energy audit data).

(b) Initiate training programmes for staff according to need. Consider preparing a pamphlet of energy economy for the employees' home use before involving them with energy matters in the authority. Promote energy conservation as an unavoidable part of our future way of life.

(c) Plan and conduct a continuing programme of promotional activities to stimulate staff interest in energy economy including both publicity and other means of communication. Make sure the language is meaningful and appropriate to the receiver. Operational staff directly responsible for plant, transport, buildings waste control etc. to be supplied with regular feed back of energy use and cost performance to encourage continuing participation. Always try and publicise the achievement of good results - nothing succeeds like success! Staff will respond if they feel they are making a useful contribution, but disinterested staff may prove to be expensive of energy. Staff motivation may be summarised by good communications, effective participation and recognition of performance.

(d) Examine government aid schemes and keep abreast of developments through participation in conferences, courses and local Energy Manager Groups, also through Department of Energy literature (12, 13).

CONCLUSIONS

The prediction of a world energy shortage in the foreseeable future resulting in a rapid and continuing rise in energy costs provides the water industry with the incentive to improve its own energy efficiency.

Electricity is the major energy source for the industry and it is contended that the minimum cost of power is directly linked to overall minimum energy use and therefore exploitation of tariffs is an important consideration. Pumping accounts for over 80% (in some Authorities over 90%) of all energy used in the industry and the main attention should be directed to achieving peak efficiency in pumping operations.

There is scope for harnessing hydropower through the use of generators and heat pumps particularly at the head works where raw water is collected and distributed. Water economy provides a direct energy saving and waste control measure should be reviewed including the provision of water supplies at optimum pressure conditions. The monitoring and control of distribution system performance through the use of modern flexible computer based telemetry will contribute to energy economy. The consumer has an important role to play in water saving but needs motivating.

Capital investment on energy saving measures in a period when energy costs are rising faster than inflation is likely to produce attractive pay-back periods even at the present high interest rates.

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DISCUSSION

Author's Introduction

Mr Cash in introducing his paper said that much of what he had included was basic common sense and good housekeeping, and would be routine for a first class engineer doing his job efficiently. Nevertheless, it was necessary in a time of rapidly rising energy costs for the water industry to look in some detail into areas where energy was consumed and to find economic ways of containing energy consumption.

It was not easy to define the relationship between energy and cost. He had drawn particular attention to this on page 2(a) 7, and he appreciated that the subject was likely to be controversial. The water industry had little option in the matter and should accept that in optimizing energy costs, total energy use in national terms would also be minimized.

The largest energy user in the water supply industry was pumping and perhaps 85% of the total energy bill was expended in this way. This energy was obtained normally from Electricity Boards. Power tariff selection was important and depended on operating requirements, available storage, and other constraints. Every tariff provided some incentive to optimize energy costs and discussions with the Electricity Board helped to ensure the correct tariff for particular conditions. Pumping plant should never be too big because of the energy wasted in friction, and a poor load factor would cost more for the energy consumed. Reservoir storage must be fully utilized to take advantage of cheap energy periods of the day and the merits of variable speed plant, integrated water supply systems, and computer modelling should be considered to achieve better overall operating costs.

At BWWC a comparison between the Company's annual average unit cost for electricity and the averaged unit cost for all industrial consumers published by the Electricity Council had shown how effective tariff and energy monitoring could be. In 1965 when these records were first started, the Company's unit cost of electricity was about 5% below the industrial average and by 1973 (just before the oil crisis) this figure had improved to 25%. Today, the equivalent figure was 12% the fall no doubt owing partly to industrial consumers economizing with rising energy costs, but also as a result of the long term diminishing effect of the MD charge on today's energy bills.

Referring to water conservation measures, if occasionally reservoirs had to be built at levels which were too high for much of the area, then water conservation should be considered through pressure reductions at the worst points in the system. Water cost money; it had to be treated, chemicals used and it had to be pumped, perhaps many times, and economy of water resulted in economy in energy use. Examples were given in the paper of the effect on water use of reducing pressure in closed zone pumping installations through the introduction of variable speed pumps. Other tests and conversions had been completed on gravity fed zones and results from one such test might be of interest. The site consisted of an estate of 1600 houses and a dairy with a daily consumption of approximately 0.8 Ml. The zone received water at an average pressure of 76 m with a night line of 12000 l/h. The zonal pressure was reduced progressively to approximately 30 m which was found to be adequate and acceptable to the consumers. Accepting the reduced pressures as a reference point, leakage based on night line increased by 85% with the rise in pressure to 76 m and daily consumption rose by 20% of which about 90% was leakage and the remainder came from the greater use of water through 'open ends'. The saving in primary water was estimated at £1500 pa which paid for the PRV installation within one year. There must be many similar opportunities within the water industry for reducing high pressure in zones.

Verbal discussion

H.SPEIGHT (Southern Water Authority) opened the discussion by congratulating Mr Cash on having prepared not only a paper ranging widely over the practical aspects of energy conservation available within the water supply function, but one which might be regarded as somewhat aggresive in its attitude towards influencing how much of the industry's product its customers really required.

An Institution to which not a few IWES members belonged published a booklet a few years ago with the title 'What is Your Business?'. Its purpose was to direct the attention of those responsible for the management of industrial enterprises towards determining what was the real and fundamental expertise and skill existing within the unit which they controlled. Only then could there be hope of optimizing performance by the application of appropriate management techniques; the publication gave instances of imagined strengths being widely separated on close examination from the real ones.

He remembered seeing in a text-book dealing with transport within industry a statement to the effect that 'Transport adds nothing to the value of a manufactured article, but inevitably increases the price which the customer is called upon to pay for it.' Although this was fundamentally correct, it could not be applied to the water supply industry without qualification. In developed civilisations water was virtually valueless until it was delivered to the customer, and to that extent he felt that transport contributed more to its value than did its abundance or, within limits, its quality.

He suggested therefore that it might be prudent to question the nature of the business being carried out by the water industry in the UK. Despite what was said in one of the later papers he believed that the industry was, in fact, in business as a manufacturer. It took a raw material and turned it into a product of defined quality (that quality differing insofar as consideration might be directed to the clean, or to the dirty water side of the business). Having done that, the water industry transported the manufactured product either to the place where the customer wanted it or from the place where he no longer required it.

The industry's approach to the detail of energy conservation should therefore surely be that of any other industrial enterprise manufacturing and transporting a relatively heavy and bulky product. Other contributors would, doubtless, dwell on the mechanical and electrical detail of how savings could be effected but he wished particularly to take up a matter featured on page 2(a)5 of the paper. It was pointed out there that a call for less of the raw material to be processed and less to be reclaimed as the water cycle prodeeded through to the reclamation and disposal phase meant, effectively, that potential savings could be more than simply those of part of the energy required for manufacture and transport.

The practicability of influencing the water consumer to use less of the manufactured product was part and parcel of that philosophy which had come, in recent years, to be known as demand management. The interesting feature was that, also in recent years, it had become politically (in England and Wales at least) much more acceptable to be seen to be moving towards demand management rather than simply talking about its applications in an abstract way. He asked Mr Cash therefore whether he would, with due regard to tendency of political weathercocks to gyrate, add to the remarks featured (on page 2(a)17) in his paper about the apparent reluctance of the water industry to involve its customers in the whole process of reducing not only energy consumption but the general deployment of resources of all kinds in developing, producing, and transporting that most estimable manufactured product, wholesome water.

H.D.M. SPEED (Newcastle and Gateshead Water Company) referred to the points made early in the paper in regard to raw water management. Mr Cash had pointed out that compensation and regulation discharges from reservoirs could be harnessed to provide hydro power. He also noted that where a reservoir was used for river regulation, it was necessary now to review the economics of laying a direct supply pipeline and thus saving the energy dissipated down the river. The head available at Kielder dam for hydro generation was of the order of 40m but some 137m were dissipated in the fall of the river from the reservoir site to his Company's abstraction point in the lower reaches. The intake pumps at this point had to apply some 120m head to raise the water back up to the treatment plant. A direct supply pipeline could have been laid to provide the raw water at no cost in energy.

Mr Speed then gave figures which indicated that, although a direct supply pipeline would have cost almost ten times as much as the intake and pumping station and its associated short length of rising main, if an annual increase in energy costs of 10% was assumed (and this might well be a conservative figure), cash flow projections indicated that the direct supply pipeline scheme became favourable after only some 21 years. At 5% annual increase in energy charges, it took some 31 years before the direct supply pipeline scheme became favourable. Increases in the cost of energy, whether from inflation or as a result of political pressures were compound whereas interest on capital was simple. He appreciated that river regulation brought other benefits not only to the general ecology of the river but also in the increased yield available from the catchment below the dam site. Against these advantages, however, were the requirement to support the extra yield and the fact that regulation losses did occur and these might be of the order of 10%.

Very many disadvantages arose from the use of the river as a water supply aqueduct. The danger of pollution from accidental discharges and from vehicular accidents at bridges and roads adjacent to the river was substantial. It was necessary to rely on energy, probably electrical, to pump the water out of the river, and in these days of increasing industrial unrest water supplies were at the mercy of the energy suppliers; gravity supplies obviously did not suffer this disadvantage. River water was, of course, much more difficult to treat and required more complex monitoring, treatment facilities and almost certainly more chemicals and energy. From a water supply point of view, therefore, which after all was the main raison d'etre of most river regulation schemes, there were many disadvantages.

They had to realise that the days of cheap energy were over, or at the very least, deferred for several decades until some breakthrough was made in the search for a new low-cost abundant source. Meanwhile, they were nowhere near the top of the energy cost increase spiral and some re-ordering of priorities was very necessary if the price of water was to be kept down. Some education of public opinion might not go amiss, instead of reaction to vociferous minority groups.

Generalization was always dangerous, but in terms of energy conservation and long-term cost it would apparently now pay to go for seemingly high capital cost schemes which were low in energy requirement rather than low capital cost schemes which relied on heavy energy input and which would have been the choice in the 1950s and 60s. Conventional discounting techniques were not adequate and the economic sums should now include a range of pessimistic rates of increase in the cost of energy.

M.A. YATES (South West Water Authority) mentioned the reference to the determination of pump efficiency by the thermodynamic method, on page 2(a)13 and said that South West WA had proved the validity of the thermodynamic method of testing pump efficiency for the medium head centrifugal pumps commonly found in the water industry.

In experiments using the Thom, Foord audio frequency ac bridge network and platinum resistance thermometers the small increase in water temperature across the pump caused by the pump's inefficiency had been measured. Using this differential temperature reading, typically 80m°C, and the total head generated by the pump, a single point efficiency reading was obtained in less than 5 min and a full pump efficiency curve produced in 30 min. These experiments had accurately determined pump efficiency without recourse to power measurement or accurate flow measurement.

K.C. MARLOW (East Worcestershire Waterworks Company) congratulated Mr Cash on producing a paper which was a major contribution on the subject of energy conservation both to the Symposium and to the industry generally. Similarly to Bristol Waterworks Company, East Worcestershire Waterworks Company (EWWC) had been preoccupied with the task of keeping energy costs to a minimum, always bearing in mind that consumers had to be assured of continuity of supply at all times. The approach at EWWC had involved the development of a mathematical model of the supply system complete with all the constraints and restrictions of plant, together with an interractive model of the electricity tariff. As a result of data input from the telemetry system, it was possible to obtain an accurate prediction of consumption in each of seven supply areas, thus enabling an optimized pumping schedule to be automatically provided to meet predicted demand at 'least cost' within a preset band of reservoir level operation. This enabled reservoirs to be operated down to limits hitherto considered unacceptable and large reservoirs were now allowed to cycle down to 30%. This low limit was, of course, subject to seasonal variation.

Mr Cash's paper had indicated that savings were to be achieved by a combination of good housekeeping and tariff manipulation, and undoubtedly the work involved in producing the predicted optimizer had made EWWC very much aware of the effects and implications of the tariff and had enabled some savings to be made, whereas the subsequent optimization caused a further 4½% saving in electricity costs by tariff manipulation and full use of reservoir storage. Although energy reduction could be achieved by manipulation of the plant to suit the electricity tariff, care must be taken to assess the increased maintenance costs incurred by revised pumping strategies.

The reduction of waste by pressure control was a most interesting aspect of the paper and the author's views were asked on using the local intelligence available in some telemetry outstations to monitor and control pressure, thus enabling the system to respond to demand. This local intelligence could also be used at outstations employing variable speed drives, especially those of the variable frequency inverter type, to calculate instantaneous efficiency of these units and ensure that this was within acceptable limits.

Finally, mention was made of the appointment of an Energy Manager - yet another specialist. It was thought that the industry should be seeking to motivate and involve existing professional staff in energy saving programmes using existing management structures.

K.B. CLARKE (East Anglian Water Company) was very interested in the remarks in the paper about computer prepared, least cost solutions and their use by a Sources Committee. His company had been forced to this technique by the complicated nature of their pumping system and by considerations of staff involvement. Their early ventures into least cost, linear programming solutions were disappointing because of continual discovery of new constraints and a staff scepticism of the results.

To overcome this they had built a computer game. It was really a computer model of the system on which any situation could be represented. The programme then did two things: it gave a printout and display of reservoir levels to show that the pumping schedule would work, and then gave a detailed costing of electricity, diesel, and treatment costs. The avowed object of the game was to produce the least cost, but the actual object was to teach the participants where the real savings were to be made. His company were now looking ahead and would be following the lead of other water undertakings into computerized telemetry. He asked whether the author thought that computerized telemetry would get the best out of his staff as decision makers.

R.G. COOK (Anglian Water Authority) said that his authority had a power bill which at present day prices amounted to about £9m, and obviously warranted close inspection. The authority was in the process of an Energy Audit. Because of the present constraints on manpower, procedures used in the audit were fairly simple, and concentrated on those areas with the greatest potential benefit. The exercise was already producing significant reductions in expenditure along with associated savings in energy.

Reference had been made to the need for educating employees and this should be stressed. It must be appreciated by all, including senior management, that they were living in a changing age and traditional practices were frequently no longer economic.

The supply to a population of about 150,000 served as an excellent example of the dominance of past practice. Water was abstracted from a river, treated, and was pumped continuously into supply, balancing against reservoirs on high ground. Investigation revealed that continuous pumping was unnecessary and that pressures could be reduced without affecting consumers. Operating practice had been conditioned by traditional views. The saving in operating costs had yet to be evaluated but would probably be in the region of 10-15%, with the added benefit of saving in energy arising from the reduction in pressure.

There was one specific opportunity for looking at energy conservation worthy of mention. This occurred when capital expenditure was imminent and a scheme underwent the process known as project appraisal, which was essentially a semi-formal process of justifying the need to spend. This provided an excellent opportunity for looking at energy conservation. A water supply scheme carried out recently illustrated the point. A number of boreholes pumped directly to a small reservoir and the project provided additional storage. The first appraisal report referred to a consultants report dating from 1962 which had concluded that the area was deficient in storage. This was not accepted as satisfactory justification and the scheme underwent detailed investigation. The final arrangements comprised new borehole pumps, rezoning of the distribution zones, and a smaller reservoir, all for similar capital expenditure but with reduction in power costs of 30%. It was likely that the final solution did not emerge in the first place because of inadequate consultation and inflexibility between various departments and it was suggested that there was a great need for all departments to work closely together, e.g. supply departments needed to work in close conjunction with the distribution department and likewise with new works.

There was a need to educate and a need for some previous practices to die. He suggested that an excellent way to begin would be for all concerned to read Mr Cash's paper.

W. BANKS (Northumbrian Water Authority) said that many impounding reservoirs incorporated turbines to recover energy from compensation water releases. 'Direct supply reservoirs' seldom had potential for generation from abstraction releases if the pipelines had been sized to match the system capacity, although maximum return on capital expenditure was achieved if power could be absorbed at the terminal treatment works.

River regulating reservoirs had a much higher potential for power generation. The Kielder reservoir, currently nearing completion in the north east of England, could generate up to 6.2 MW when abstracting at the maximum release rate. Although it was in the national interest that energy of this magnitude should be recovered, the Northumbrian WA had examined this hydro-electric project on no less than four occasions and it was only when last examined early in 1979 that the project was considered to be economically viable. This decision had coincided with restrictions on capital expenditure such that £4.1m could not be allocated for this purpose due to higher priorities elsewhere.

One of the major problems with hydro-electric generation at impounding reservoirs was that the demand for energy at the reservoir was usually very small and a large proportion of the power generated had to be exported to the Electricity Board system. If energy could be used locally at an adjoining treatment works, the scheme became much more viable. A unit currently exporting power at a rate of 65 kW to the grid system in the north east of England was realising 1.68 p/kWh. The Kielder Scheme, if developed, would export power at 1.51 p/kWh at present day prices, whereas a third scheme currently being considered for installation at an existing treatment works could substantially reduce the power intake to the works at a current saving of 3.0 p/kWh.

They should be conserving energy now in the national interest and there was scope for greater financial co-operation between water authorities, the Department of Energy and the Central Electricity Generating Board to make such schemes viable, particularly at river regulating reservoirs where excess water was frequently available in winter for generating purposes. If used selectively during peak winter peak day periods, the energy could be of considerable benefit to the CEGB.

Finally, he referred to the distribution examples on page 2(a) 15. One of the examples was a variable speed pump to maintain a constant pressure in the distribution system. Even greater economies could be made by monitoring the pressure towards the end of the distribution system and telemetering this back to the pumping station where the delivery pressure could be used to control pumps to maintain a constant terminal pressure at all times. This guaranteed minimum power consumption at all times and also assisted in reducing demand due to lower distribution pressures.

Written discussion

J.S.M. WILLIS (Consultant) wrote that the rise in the real cost of energy, and prospective shortages, had made it necessary to have a major rethink about policies which the water industry might have previously taken as settled. The examples of pumped storage and river regulated schemes had already been mentioned, but there were others. Should, for example, all consumers be required to install water storage sufficient to balance out their rates of demand? At a stroke this would save energy by increasing load-factor and reducing friction losses, and, at the same time, lower the size requirement for pipes and pumps; (although it might mean sacrificing that sacred cow of the byelaws, the tap-on-mains-pressure that customers were supposed to recognize as the preferred source of their drinking water).

The sizing of pumping mains must also come under scrutiny. Sizes were usually determined after an appraisal of the costs of pipelaying and plant, and a forecast of the costs of energy. What were they now to assume for the latter? The rise in the relative cost of energy must tend to a choice of larger main sizes and led to a conflict between the need to save capital and to save energy.

Finally, with unemployment and the costs of chemicals and energy all rising, were they about to see the slow sand filter restored to general favour?

M.J. ROUSE (WRC Engineering Centre) wrote on the subject of conservation through pressure reduction as discussed on page 2(a) 14. Theory, of course, supported the square root theory but the results reported in the Report of the Working Group on Waste of Water were based on actual measurements. It was not known why the rate of losses increased with pressure, but it was not unreasonable to assume that at the higher pressures existing leak paths were increased in size (particularly at joints) and that perhaps some new leak paths were established. The square root law would only apply to constant size orifices. As Mr Cash had rightly said in his paper, the important point was that there was a substantial reduction in leakage water when pressure was reduced. What the results of the Working Group on Waste of Water were indicating was that the actual savings were even greater than would be suggested from theory.

I.S. SUTHERLAND (Gilbert Gilkes and Gordon Ltd) wrote that Fig.1 showed the hydro-electric site power potential based on an efficiency of 85%. This efficiency was possible at the higher outputs but not at the lower end of the power scale. Typical alternator efficiencies at various outputs were 85, 89, 93 and 95% at 25, 100, 500, and 1000 kW, respectively. These efficiencies must be multiplied by the turbine efficiency which would vary between 78 and 90% depending on the size of the turbine and its operating conditions.

In addition to the conventional use of hydro power to produce electricity, consideration should also be given to using hydro turbines to directly drive pumps or other rotating machines. This saved the electrical losses in the alternator and drive motor as well as allowing speeds other than synchronous speeds to be used. Costs could also be minimized using this form of drive by cutting out turbine governors. (The pump, etc. must be designed to withstand the overspeed condition which would occur if the load was suddenly removed, and allowance must be made for higher pressures in pumping mains). Small turbines (called water motors) were available to provide drives from less than a kilowatt up to 20 kW. These were safe for use in hazardous atmospheres and were not adversely affected by load-induced stall conditions.

R.V. ASH (South West Water Authority) referred to the use of PRVs as a means of reducing pressure to reduce waste in a gravity fed system. This was common practice, but it should be recognized that PRVs required a high level of maintenance to ensure reliable performance and that if a PRV failed, the consequences would be increased wastage and, possibly, an expensive burst main repair. If the circumstances and topography were suitable and space was available, a small break pressure tank strategically located would be more reliable and less troublesome, even though a nominal length of additional supply main would need to be laid. A cost balance would indicate the alternative to be employed.

In the context of pressure control of an entirely pumped distribution system, particularly in a relatively flat area, it would be prudent to ensure that the distribution network was operated in its most effective arrangement relative to the number and magnitude of the pumped sources and the relative magnitudes of consumption in the various parts. In these days of rapid development of computer facilities, it was very much easier to carry out distribution network analyses simulating the levels of consumption in the various parts and determining optimum pumping required from the associated sources. Such analyses would further demonstrate inadequacies of the distribution network showing, for example, where existing zone valves should be opened or closed, where new zone valves should be installed, and where new link or reinforcing mains should be laid. The cost of carrying out such analyses and the provision of such minor supplementary works would be more than offset by the early savings in energy costs with the reduction of pumping head and optimized pumping regimes. Such analyses would further identify the locations for critical pressure monitoring and pumping control, relative to the respective sources and the optimized pumping regime, the use of which should be related to the cost of providing associated telemetry, as emphasized by Mr Cash.

J. de C. BAKER (Southern Water Authority) wrote that Mr Cash had put forward a most useful check list for existing installations.

A detail study of each works on this basis was time consuming. It was useful to identify the 'rogue' installations where large improvements were possible and put this work in hand before undertaking the detailed study. Such installations could be identified by a low value of overall efficiency.

For this purpose overall efficiency as a percentage (η) was defined as:

$$\frac{\text{energy to lift water from source to service reservoir}}{\text{total energy input to installation}} = \frac{2.725\ QH}{I}$$

where
H = static head, source to reservoir, m
I = total energy input, kWh
Q = quantity lifted to reservoir(s), Ml

Multiple source sites with re-lift pumping to several levels could be conveniently handled by summing the products QH from each source to station reservoir and the products QH from station reservoir to service reservoirs.

An initial survey could conveniently be made on an annual basis. There appeared to be some merit in continuous monitoring on a monthly basis, in which case it was necessary to flow integraters and electricity meters at sensibly the same time to minimize errors.

The advantage of calculating efficiency in this manner was that it included all ineffective power consumption such as friction in mains, treatment plant power consumption, and works heating. System deficiencies identified by this method included high friction losses which had gone unnoticed because of gradual increase in demand over the years, throttled pump delivery valves, and inappropriate pumping routines. Incidentally the high friction loss was reduced by cross connecting the pumping and gravity flow mains, a simple solution providing that regular turnover of the service reservoir could be maintained.

Typical overall efficiency figures obtained were:

5 Ml/day unmanned borehole source, high head low friction loss:	0.65
65Ml/day surface water source:	0.58

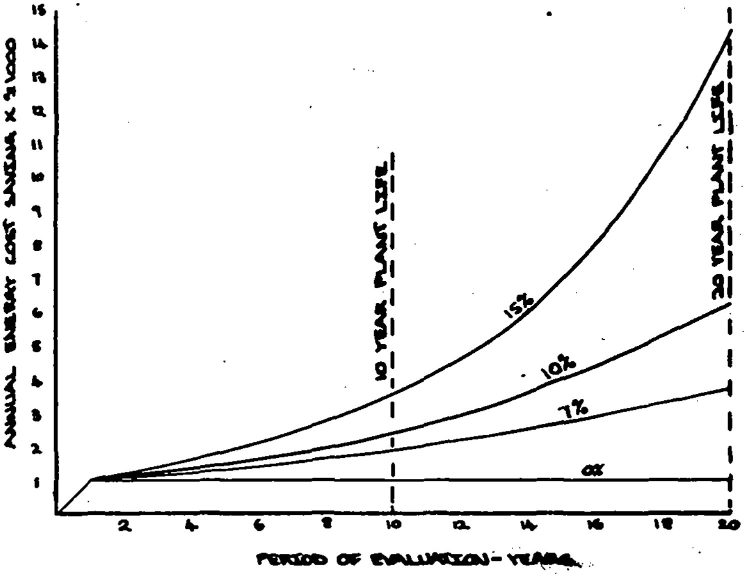
Author's reply to discussion

The author thanked the speakers for their comments and replied to the detailed questions and points raised as follows:

Referring to Mr Speight's opening remarks leading into the subject of demand management, it seemed incongruous that Water Authorities were spending time, effort, and cost to reduce waste of water within their own system while adopting a comparatively passive stance towards the consumer and the way he used water. It had been said that until the water industry put its own house in order it was unwise to expect the consumer to make economies, and a national publicity campaign in support of this was unlikely to receive NWC approval. This was a pity and in the fight to contain costs (including energy costs) it seemed that the consumer was not to be involved in the total effort.

It was gratifying that the NWC scheme for the testing and approval of water fittings was in operation as this allowed for specific tests of water consumption on dish washers, washing machines, etc., though the scheme would be more effective once the Department of Industry had accepted the NWC certification trade mark. Much was known about the way the domestic consumer used water and the metering option now available would have long term implications for water economy, but this must be accompanied by publicity to help the consumer help himself. Was there a case for the Water Authority to subsidize the provision of dual flushing arrangements in domestic dwellings? In any event unless the public were constantly reminded through attractive publicity that individual economy in water use mattered and helped to stabilize rising costs, then water charges would continue on their upward path.

He was grateful to Mr Speed for drawing attention to the changing situation with rising energy prices which could result in some river regulation schemes involving energy dissipation in the river bed being unacceptable when compared with the economics of laying a pipeline to link the reservoir with the water treatment plant. Every case must be taken on its merits and reference had been made to the relationship between the 'fixed' capital charges for the energy saving works and steadily rising energy costs (see Fig.4). It was possible that relatively high capital expenditure on energy saving schemes could be justified because of the expected long term growth in energy prices. The difficulty was to decide the 'acceptable' pay back period. It was suggested that any scheme showing a 10 year or less pay back period was attractive, but much longer periods could be justified depending on the realistic life of the asset (e.g., a pipeline or pumping equipment).



First year saving = £1000
Percentages refer to energy price increases per annum.
Interest rates on capital for energy saving schemes
are fixed from year one.

Figure 4 The effect of cost increases on annual saving

Mr Marlow's remarks had highlighted the importance of computer based telemetry in monitoring reservoir levels and pumping operations to obtain the very best utilization of resources including power tariffs. The computer modelling of the supply system linked with the interactive model of the tariff with the results programmed into the telemetry, was moving close to the perfect solution for energy costs. The suggested maximum use of reservoir capacity to minimize energy costs was admirable even if this was achieved through a marginal reduction in consumer service. Limits on minimum reservoir levels could be set according to time of day, day of the week, and time of the year with the flexibility of the telemetry allowing these changes to be made easily.

Mr Marlow had sounded a word of warning about changing the operating mode of pumps to obtain the best results from tariffs and it was assumed that he was referring to the undesirable side effects of fluctuating borehole water levels with risk of damage to the aquifer and the transmission of loose material into the pump. Every case had to be examined on its merits and a reduction in overall operating costs as well as energy costs proved.

To use the telemetry for controlling pressure in the system either through pump speed control or remote resetting of PRVs was well worthwhile particularly as most systems were designed for 'worst' demand conditions implying surplus pressure for most of the day. The use of locally placed telemetry intelligence was an admirable way of managing the water system both on zonal pressure control and best pumpset efficiency. Would it be an advantage for the controlling parameters to be capable of resetting centrally to preserve absolute flexibility?

Mr Marlow had questioned the need for an Energy Manager and undoubtedly small undertakings had to rely on training existing personnel and using consultants where appropriate. There was a risk in this however of producing 'a jack of all trades and master of none' and in the author's view an Energy Manager should be appointed where possible to mastermind the energy conservation drive within the existing management structure.

He was grateful to Mr Yates for providing further information about the thermodynamic method of site pump efficiency measurement. This had obvious advantages on traditional methods especially when tests could be completed in half an hour without having to rely on flow measurement. However, there did appear to be some doubt at the moment whether this specialized equipment would be commercially available to the industry in the future in view of the potentially limited market.

Mr Clarke had referred to the expanding use of telemetry and computer modelling for least cost operational solutions at EAWC and how this might affect his staff as decision makers. There was no doubt that water supply systems today were complex and interactive with many constraints, and the most efficient least cost operating solutions could only be provided by using computer based telemetry and controls. It was important for staff originally involved in these operations to understand what was happening and a communications/training exercise was very important to avoid frustration. At BWWC as new telemetry was installed with greater centralization of data, staff were being kept fully in the picture and furthermore, local station chart records were being retained for the time being until centrally processed telemetry data could be relayed to the Divisional Offices through the VDU/Keyboard/ Printer. The duties of the operational staff remaining would change in that they would receive better organized data more rapidly about their water system enabling duties to be carried out more effectively, particularly in fault diagnosis. Staff had to be encouraged to adopt a flexible attitude to changing work situations and the likelihood was that the station operator would find himself with wider horizons of work involving groups of stations or local water systems on which he would be better informed through his telemetry data terminal.

Mr Cook had provided some excellent examples of the importance of applying sound engineering principles in assessing the efficient operation of an existing scheme and in project appraisal for a new scheme. In both examples energy considerations had played a part in the final configurations of Works. This fitted in precisely with the author's introduction where it had been emphasized that energy (with other) considerations were liable to be assessed as a routine by a first class engineer doing his job efficiently. What mattered was that in assessing capital expenditure, allowance was made for the inflationary trend in energy costs.

Mr Banks had referred to hydro electric generation and correctly assessed the major potential to be in the discharges from regulating and impounding reservoirs. These were usually sited in remote areas and the cost of generation was increased because of the long transmission lines required to connect power to the grid. At Bristol the local Electricity Board was actively in consultation with the Water Authorities on potential sources of hydro power. Relatively low capacities; 10-20 kW, had been mentioned though it was felt that generation for export could not be justified on economic grounds below 40-50 kW. On the subject of variable speed pumps to maintain constant pressure in the distribution system, he agreed that the best results would be obtained by transmitting a remote reading pressure signal from the 'weakest' point in the system to initiate pump speed changes. In the examples quoted in the paper it so happened that the pumping station was at the highest point and the station delivery pressure was in fact the correct control point.

Mr Willis had suggested that all consumers could be required to install storage to even out their rates of demand with no taps connected to the service pipe. Assuming that the man-made byelaws problem and the increased risk of contamination etc., could be overcome, the prospect of overall pressure reduction in the water system and pipe size reduction for new schemes could be very attractive. The cost of property conversions would have to be weighed against potential savings in water, energy, and capital resources. Perhaps this was an area for future study by the industry with the WRC?

On the subject of slow sand filtration versus RG filters in energy terms, the former would probably be more acceptable. It was interesting to observe how the slow sand filter had gone out of fashion in the last 30 years, but was now making a strong come back certainly on grounds of better final water quality in some circumstances.

Mr Rouse had referred to the relationship between water conservation and pressure reduction, and rightly emphasized that actual savings from the tests carried out by the Working Group on Waste of Water were even greater than suggested from theory and this was a further incentive to Water Authorities to optimize system pressures.

He was grateful to Mr Sutherland for correcting the figure of 85% quoted for turbine efficiency which, of course, would vary according to the actual sizes of the machines. The use of water turbines directly coupled to pumps was interesting but less flexible to use than the generator and therefore likely to have only limited application in the water industry.

Mr Ash referred to the small break pressure tank as an alternative to the PRV for reducing pressure in distribution zones. He was right to balance the higher capital costs of the one scheme with the higher operating costs of the other. The total annual charges of the cheaper scheme must still be less than the annual savings from water economy. Regular bursts in a PRV zone suggested incompatibility between the operating characteristics of the system and the valve design (often the valve was sized too large for effective control). BWWC had many zones which were supplied via PRV installations and the majority had performed quite satisfactorily although there were isolated examples of burst mains, generally because the valve had failed to operate correctly. He agreed that routine maintenance of PRVs and PSVs was very important for reliable operation.

Mr Baker had raised an interesting practical point on the monitoring of installation performance, that of producing a simple measure of station efficiency which would direct staff to the worst 'performers' first. The industry faced an enormous task in carrying out the detailed survey and subsequent monitoring of station operation in line with the suggested energy check list (pages 2(a) 11 and 12), and the proposed quick check method was admirable. However, the annual energy cost of stations must also feature so that the 'low efficiency - high cost' stations received priority. At BWWC comparisons were made on the basis of power cost in '£/Ml/10m head' for categories of installations and the Company total average figure for 1979/80 was £1.02. The Company also used an alternative comparison of 'units consumed per Ml metre' and this had the advantage of omitting the varying cost factor. The average figure for the last 3 years was 5.06.

2(b) WATER TREATMENT PLANT: DESIGN AND OPERATION FOR LOW ENERGY USE

R.A.C.Coates B.Sc. M.I.C.E*

The author considers three separate but related issues concerning plant design for low energy use. Firstly, he states that tender documents need to reflect the importance of energy savings and inform the designer of the upstream and downstream conditions. Secondly, he points out that the greater the designer/contractor's responsibilities, the more energy savings can be shown, as these are inter-disciplinary. He then reviews each of the normal water treatment process stages highlighting energy issues to be taken into account by the designer.

PART A - CLIENT TENDER DOCUMENT CONSIDERATIONS

It is important to recognise that the way goods and services are purchased has an important effect on the goods and services eventually procured. In the case of a water treatment plant the client is attempting to buy a number of separate qualities related to the plant. These can be considered as follows:

Price

This has separate parts related to mechanical, electrical and civil design and construction, each part has a number of values depending on whether one considers to-day's tendered capital cost, the future project completion costs and the long-term costs of financing, maintenance, operation, and running costs. The latter must be split into labour, consumables and spares, chemicals and energy costs.

Performance

This is related to questions such as - will the plant achieve the performance standards laid down in terms of quantity and quality and over what period of time? Will after sales service be available and technical support?

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In addition there is the performance of the design/construction companies during the execution of the contract, for example, with what reliability will the completion date be met? and what level of supervision will be necessary from the client?

Public Accountability

This is related to such questions as - can the purchasing authority demonstrate that value for money has been obtained?

As can be seen, many of the above qualities can only be quantified after the event and require experienced judgement. Unfortunately the need for public accountability has tended to lead to over emphasis on price and to counteract this clients' evaluative procedures have to become more sophisticated over time to ensure the other factors are considered.

The energy consumption of a water treatment plant can be estimated in advance and if a client wishes this to be properly evaluated by potential suppliers and designers, it is essential that a formula for the relative importance of energy costs is included in the enquiry documents. This must be in the form of capitalising annual energy costs over a period of time with the client specifying energy costs and interest rates for a given number of years together with the anticipated plant utilisation. Without such a mechanism it is impossible for the designer/constructor to establish the relative weighting of capital costs to running costs and the lowest capital costs will usually be pursued as historically that has been the main buying incentive of Water Authority clients.

In order to allow the designer to fully consider energy costs the client must specify information related to the following:

Definition of Utilisation

The build-up of flow through the plant over time and whether it will be providing relatively constant base load or fluctuating flow. Decisions on the number of streams and plant units to be employed to match the stages can be important to avoid inefficiencies in turndown and unnecessary head loss through over control.

Definition of Overall System Hydraulic Gradient

The overall hydraulic gradient of the scheme, particularly that immediately upstream and downstream of the plant. This is very important to ensure:

Upstream

Surplus energy is utilised rather than wasted in the design of the inlet works and/or mixing. (This is further discussed under Process Considerations in Part C.)

Downstream

The minimum gradient is achieved through the works with a maximum level being achieved in the clear water tank.

Overflow

Where available head is very small, the requirement to provide a surcharge during emergencies to overflow weirs can result in a head loss during normal operation. Whilst this situation is rare it is extremely common for additional civils costs to be involved to meet this surcharge upstream of the overflow weirs. The use of partially primed siphons may alleviate this difficulty.

It is necessary to emphasise the importance of the hydraulic gradient and the client's decisions on pump controls, pump staging or variable speed pumps upstream and downstream of the plant. As in all water treatment processes the main energy cost is associated with the pumping of the total throughput of the plant and, of course, the designer/contractor only has an ability to influence these matters if they are part of his contract.

PART B - DESIGN/CONTRACTOR'S RESPONSIBILITIES CONSIDERATIONS

From Part A above it is evident that it is necessary to include the energy costs responsibility within the designer/contractor's responsibilities, if this is to be adequately considered. In just the same way it is evident that if contracts are let on the basis of separate disciplines, i.e mechanical, electrical and civil, it will be very difficult to establish what savings in capital and running costs one contractor has achieved at the expense of other discipline costs. In order to demonstrate this point a case study will be mentioned from a plant designed and constructed by Degremont Laing for the Anglian Water Authority at Wing.

In this case the client had called for a complete turnkey contract incorporating mechanical, electrical, and civil design and construct. It was stated that energy costs would be considered as part of the adjudication of tenders. The plant was a 280ml/d (62 MGD) Scheme and the water was pumped both to and from the works thus making the hydraulic gradient a critical issue.

When carrying out turnkey tender designs it is normal practice within Degremont Laing to evaluate alternative design and construction solutions, particularly where process and/or mechanical electrical changes can be made. In this instance one of the studies that was carried out was to optimise the filter control system in order to reduce the head loss through the plant. Fig. 1 & 2 show a schematic plan and section of the filter control system. This can be compared with the more conventional system where the water is distributed over weirs from the common filter inlet channel into the filters. The Wing system measures the level in the common inlet channel and by modulating all the 12 filter outlet valves it maintains a constant level. (Each valve contains a feed-back loop from its own flow measuring device to ensure that each filter passes the same flow irrespective of the cleanliness of its bed. This system by saving a weir at the filter inlet reduces the hydraulic gradient and therefore the energy required in the total system.

This had the effect of reducing the civil engineering content as the excavation and construction of the filter bank was reduced. These savings more than outweighed the additional cost involved in providing a more sophisticated filter control system. This example illustrates the difficulties presented to a designer when he is faced with a large number of inter-disciplinary design solutions for which he requires cost information in order to arrive at the best overall solution. Whilst the more obvious situations could be covered by specifying more detail into the separate M and E and civils tender documents. The many minor optimisations to achieve energy saving are not available to the client when he pursues a fragmented design and contracting route.

PART C - PROCESS CONSIDERATIONS

A typical water treatment plant will contain parts of the process chain listed below:

Inlet distribution, mixing and coagulation

Aeration

Floculation

Clarification

Filtration

Sludge treatment

Disinfection.

To these processes a variety of chemicals will be dosed at suitable points to achieve the optimum chemistry for treatment, very little energy is used in the chemical dosing systems and this has therefore not been considered in this article. Each of the above processes will now be considered in turn. (Brief comments related to sewage treatment are noted in square brackets).

Inlet distribution, mixing and coagulation

The key issue here is the design of the upstream system to ensure that control is achieved with minimum loss of head. Experience suggests that this invariably means that some surplus head is available which can be utilised for distribution over weirs and hydraulic mixing. Care must be taken to consider the turndown situation where loss of mixing efficiency can result. Mixing of reagents with the raw water can be considerably improved with dilution of the chemicals after preparation. It is also important to take care in ensuring that energy consumption for mixing is not reduced such that chemicals are used less efficiently as this would result in increased dose rates. The importance of distribution of chemicals prior to mixing must not be overlooked. The use of weirs for mixing is extremely effective and quantifiable at the various anticipated plant flow rates.

[Where head is not available, and this often applies with sewage plants, both at the inlet and for later distribution between process streams, Degremont have developed a controllable partially primed siphon system which can make major head/energy savings. It has been found very difficult to market this advantage unless the project incorporates civil engineering and running costs capitalisation formula. An advanced version of a hydraulic mixer used on small industrial plants is the Degremont Turbactor which is a unit designed to achieve very rapid mixing by generating a venturi effect.]

Alternative methods of mixing which are considered include the use of electrically driven pumps, mixers and blowers. From both energy and maintenance points of view, all these must be considered as inferior if hydraulic head is available. Pumps seem to have no advantages and in turn become more inefficient as turndown occurs, electric mixers are used as flash mixers where this is necessary to achieve rapid mixing for process reasons. Air is not used in water treatment where a good floc is needed.

[Air tends to be considered in sewage and effluent processes where biological action requires oxygen. Care must be taken in using air where unwanted flotation or oxydation may occur.]

Situations do occur when water treatment plants are local to upland dams where excess upstream head can be used to generate power for the water treatment plant. If it is possible to use the energy in this way it is far better option than having to dissipate the head through expensive pressure reducing systems.

Aeration (Fig. 3)

Some water treatment plants involve aeration for processes such as iron removal, gas removal, oxygenation etc. The three main methods used are:

Gravity - splash or cascade
Spray
Bubble or diffused air.

Whilst the bubble or diffused air system is the most efficient means of oxygenating water, it requires additional energy compared with gravity or spray methods if head is available in the system.

Floculation

Floculation requires gentle motions to avoid breaking up newly formed flocs. It is usually assumed that flocs will be destroyed at velocities above 0.25-0.3 m/sec. Whilst static baffle type floculators need low energy they can result in local high velocity areas and are inefficient when flows are reduced.

Mechanical floculation is often achieved by using large low speed paddles. This can be particularly effective if it is combined with a zone of higher concentration using recycled sludge as occurs at the inlet of many clarifiers.

An interesting development of this is to combine high concentration through recirculation with intimate hydraulic mixing and low energy as is done between the plates and spoilers in the sludge blanket of a Super Pulsator. Here the pulse ensures that there is efficient floculation even during turndown conditions.

Clarification

In order to be able to efficiently treat the wide range of raw water encountered any major water treatment company will have developed a number of different clarification systems. The Degremont Group have seven main alternative systems. .

Normally the selection decision is based on process requirements which are assessed against the particular characteristics of the water involved. Whilst most waters can be characterised such that the optimum process is clear, there are occasions when two or more solutions of solids liquid separation are possible. For instance, this happens with flotation and super pulsators in some instances. In such cases the capital (mechanical, electrical and civil), energy and running costs become the key concern. Whilst current experience indicates a reduction in chemical consumption for the use of flotation for some raw waters the most important cost component is energy, as there is such a marked increase in energy costs for flotation. This is because it is necessary to pressurise (up to 7 bars) a proportion of the flow (approximately 10%). This energy consideration tends to ensure that flotation is only offered by Degremont Laing for situations where it is essential for the process, although installations can of course be justified if adjudication is based primarily on mechanical capital cost.

With regard to other clarification systems, the difference in energy consumption is very small and it is therefore unlikely to be a determining factor in the selection of the equipment.

Filtration

In optimising filter design the normal two key issues are:

How well does it perform as a filter? and
How repeatable will its performance be after washing?
that is, how well does it wash?

These criteria are affected by the characteristics of the particles to be filtered, both the type of material and quantity. Consideration of these criteria focuses decisions to be made on the following:

Choice of media, mono graded sand/or dual media
Depth of media
Type of underdrain system
Filtration speed
Backwash, cycle, velocities and method, i.e air and water together or separate, etc.

In addition to these process decisions the control philosophy of the plant must be considered, that is the level of sophistication/automation to be used, which in turn will depend on the type of maintenance and support that is available.

With downflow filters there are two modes of operation (see Fig. 4). These are Constant Rate either using modulating control valves or rising head, and Declining Rate. Whilst the latter has a major head advantage it has process quality disadvantages, some operation difficulties and additional capital costs as the average rating of the filter has to be reduced. The rising head alternative carries a civils capital cost disadvantage.

All the above decisions will have a bearing on the energy consumption which will be related to:

Hydraulic gradient - minimum head loss. This is obviously most critical as it affects every m^3 of water treated.

The quantity of backwash water - both per wash and the total to be handled. This involves the wash water both pumped through the filters and re-handled through the total system. In addition, water drained from the top of a dirty filter has to be re-handled in a wash water recovery plant. This increases if, say, a rising head filter is chosen instead of a constant rate.

The quantity of backwash air - this tends to involve a relatively small energy content for generation of low pressure air.

It can be seen that considerable expertise is necessary to handle such a large number of variables and relate them to capital and running costs.

Sludge Treatment

In current water treatment plant technology, sludge treatment does not offer a great deal of opportunity for energy optimisations, other than ensuring that equipment is properly sized for the purpose and that the correct polyelectrolytes for sludge treatment have been selected to ensure that the thickest possible sludge is being handled.

[In sewage treatment the energy savings (and generation of energy from anaerobic sludge digestion) from correct process selection are, of course considerable. As clients become more aware of energy production benefits the process refinements developed to ensure the optimum environment for the biological action are creating more interest. The energy gains from this expertise are also accompanied by considerably reduced civils capital costs due to the reductions in digester retention times.

This is another example where selection based on mechanical costs only is very suboptimal as additional equipment is needed to ensure proper process control. The Degremont developed system of unconfined gas mixing ensures very rapid and complete mixing of the digester contents and this linked with control of temperature, sludge feed rate and concentration creates the correct biological environment to provide the lowest system capital and running cost.]

Disinfection

Whilst it is possible to consider energy consumption requirements for the alternative disinfection process involving Chlorine and Ozone the selection is normally based on process considerations linked with user acceptability.

Where transportation of chlorine products is extremely expensive especially overseas it is becoming more common for onsite chlorine generation to be considered.

In selection of Ozone systems (e.g medium or high frequency) it is necessary to consider the balance between energy costs and capital costs.

CONCLUSION

The Author has attempted to show the complexity of decision-making related to process needs, capital costs and energy savings. Whilst it is essential that plants are designed to use minium energy this goal can never be pursued in isolation and can be considered to be a dangerous objective if carried out by engineers lacking the support of the other disciplines involved. Energy optimisation requires a multi-disciplined system view of a total plant not the fragmented approach that so many of our institutions inadvertently encourage.

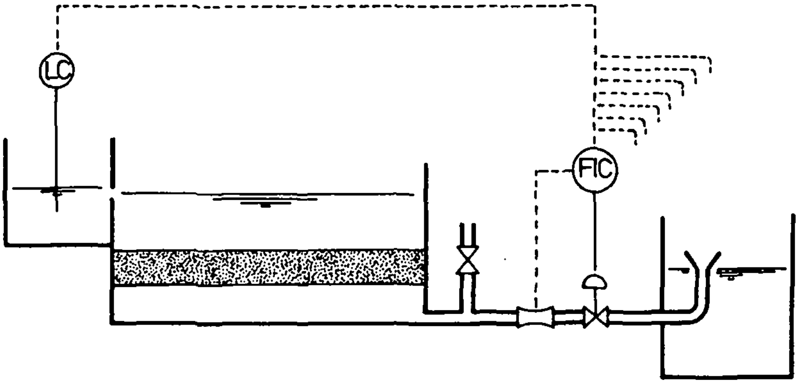


FIG. 1 WING W.T.P.—VIEW SHOWING ONE FILTER AND ITS CONTROL SYSTEM

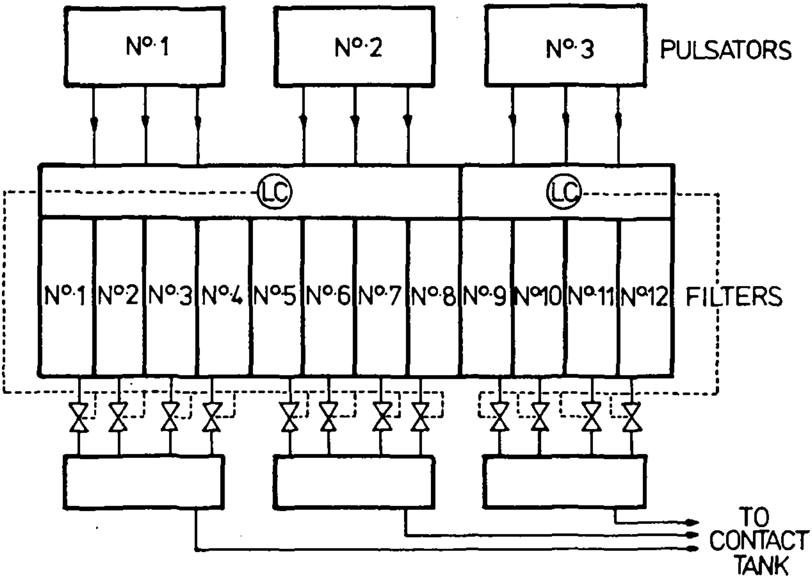
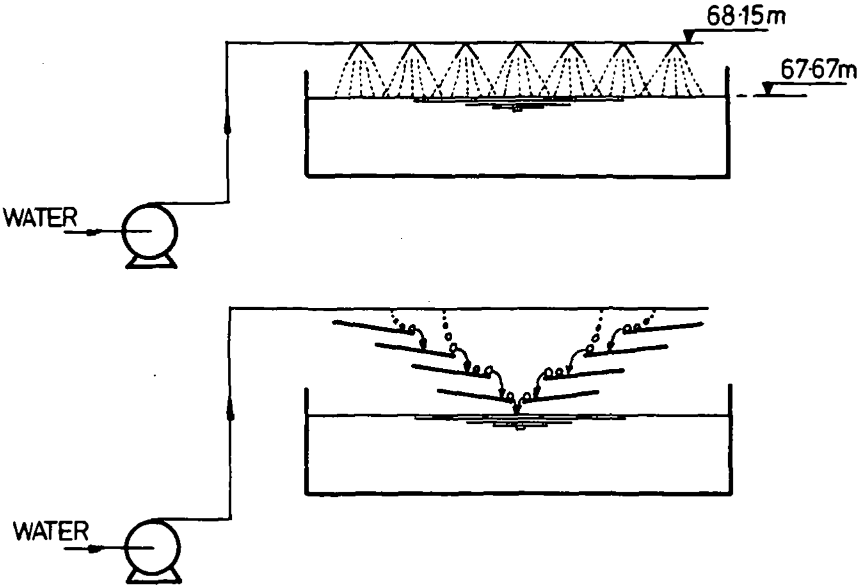


FIG. 2 WING W.T.P.—PLAN VIEW OF SYSTEM



SPRAY AND CASCADE AERATION SYSTEMS

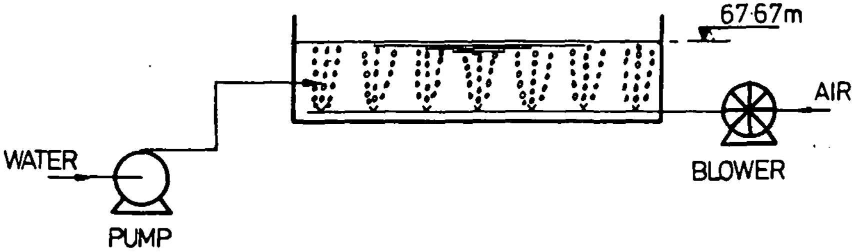
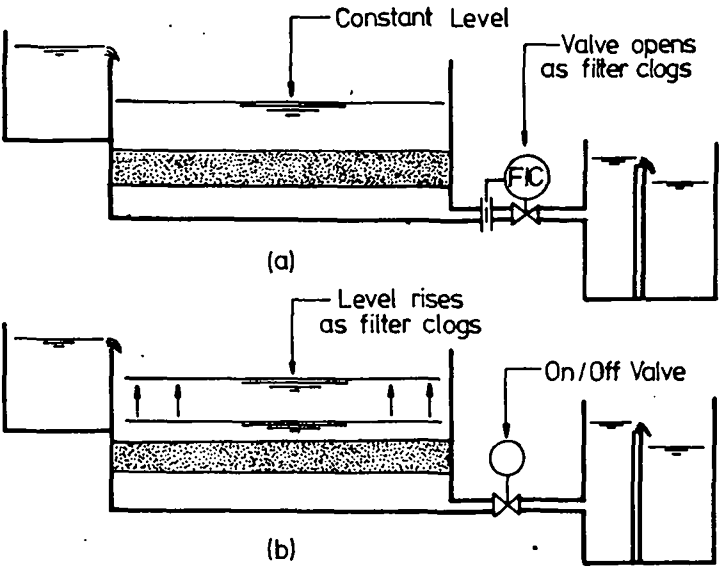
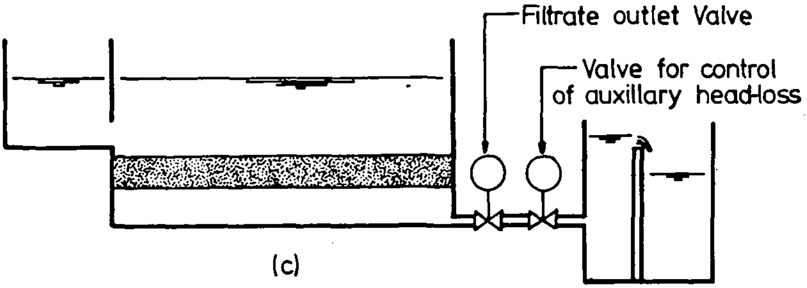


FIG. 3 DIFFUSED AIR AERATION SYSTEM



(a) CONSTANT LEVEL—CONSTANT OUTPUT FILTER
(b) RISING HEAD—CONSTANT OUTPUT FILTER



Note:- The cleanest filter in a bank of declining rate filters receives the greater proportion of the inlet flow.

FIG. 4 (c) DECLINING RATE FILTER

DISCUSSION

Author's Introduction

Mr Coates introduced his paper by saying that it was immediately apparent that there were no new esoteric theories, no simple panaceas, and no prescriptive statements: do it like this and all would be well! It was equally evident that there was no going back to yesteryear to those plants that did not consume energy. Cost and land use structure would not allow a return to techniques like slow sand filters.

He had found that the most fruitful thinking developed from asking questions like:

- What was stopping energy savings being made?
- What happened in those cases where energy savings were achieved?

The general answers to these questions suggested that additional energy savings required a higher level of integration to be achieved than normally existed. They required a total systems approach to the problems and a bridging of the existing barriers.

When he used the term barriers he meant all those artificial boundaries that had been created in the past to simplify the organization of the various tasks. They existed between the disciplines associated with plants, i.e. the process, the mechanical, electrical, and civil engineering. The timing of different stages also created divisions such as those between design, construction, and operation. In addition, there were the institutional barriers dividing up the different types of organization such as those between consultants, contractors, clients, and consumers.

The challenge was to think about and create ways to integrate actions across these artificial boundaries. At each interface they had to know what mattered most to achieve energy optimization. They had to consider how the structual mechanisms (organization, responsibility, specification, contract conditions) could be set up to encourage what they wanted to achieve.

In the first part of the paper, emphasis had been placed on the need for energy usage to appear to be important to the client and to affect his buying decision. The client needed to do this by giving all the necessary systems conditions with regard to operating head and usage patterns. The client needed to demonstrate that the cost of energy would be considered in the adjudication process. He could not overemphasize these two points: firstly, because it was impossible to make real total system savings without knowledge of the head available upstream and the ideal conditions downstream and, secondly, because the ultimate commercial judgment was so often lowest capital cost.

This point had been emphasized by an earlier speaker, Mr Cash, with regard to selection of pumping units. In that case it was even more important as it was evident that the energy consumed in the water industry was almost all concerned with pumping and distribution.

In the second part of the paper, a case study had been used to demonstrate an energy and capital cost saving that would not have occurred if the contract had not been a design and construct contract. He did not wish to add anything other than saying that the integration of engineering disciplines in very cost conscious project teams had cut across the normal design, construction, and engineering discipline boundaries, and had in his experience been a very effective way of maximizing energy and capital cost benefit for the client. To work in a team where information was shared and conflicts constructively resolved to meet commonly held objectives was obviously beneficial to all concerned. It was a marked contrast to the more usual alternative of inter-departmental, inter-organizational arguments causing delays and increased costs.

In the third part, the various process stages were reviewed in an attempt to show how energy savings were intricately bound up in the fabric of process considerations. Although energy savings will be of primary importance in a minority of cases, normally they will represent marginal optimizations on the process chosen for its treatment capabilities.

Verbal discussion

J. JEFFERY *(North Surrey Water Company) said that Mr Coates had presented* an interesting paper which not only gave some useful ideas on process considerations but also introduced some more philosophical issues.

The first part of the paper had dealt with client tender document considerations. He was sure that Mr Coates was right when he said that the industry had in the past generally looked for the scheme with the lowest capital costs. In the same paragraph he had said that energy costs must be capitalized in order to establish the weighting of capital costs to running costs, but of course comparison of schemes might also be made by converting all costs to revenue costs. The description given in Part B of the paper of the 62mgd plant designed and constructed for Anglian W.A. by Degremont Laing was interesting, but would be even more so if supported by figures. In particular, was an estimate available for the energy saving produced by saving a weir at the filter inlet, and by how much did the civil engineering savings exceed the additional cost of the more sophisticated filter inlet control system?

Turning to Part C of the paper - process considerations - he asked Mr Coates for his comments on the suggestion by Mr Cash in his paper that process automation was likely to be more efficient than manual operation. Also in Part C of the paper Mr Coates drew attention in the section on mixing and coagulation to the need to ensure that energy rates were not reduced to the point where efficiency of chemical use was impaired. This was an important point. Theoretical consideration of hydraulic mixing often assumed that the plant would always run at maximum throughput. This was not often so and variations in plant throughput could considerably affect the mixing in such systems; occasionally to a point where little mixing occurred. A variable energy input mixer which allowed the correct mixing at all flows would usually be preferable for optimizing efficiency and minimizing the use of chemicals. Later, in the section headed aeration he seemed to say that diffused air was the most efficient method, but let's use gravity or spray methods. Perhaps he would clarify that point. Mr Jeffery suggested that what was probably meant was that because most plants had not been designed with much thought for energy considerations, there was usually spare head available, so let's use it. If that was right, he assumed that in designing a system from scratch, if aeration were required, Mr Coates would arrange to provide it by diffused air. The section on clarication mentioned what he thought was one of the best examples in water treatment on the conflict between capital cost and energy costs. Although he had not had to make the comparison himself he knew that calculations of total costs of flotation and settling systems could be close and could sometimes favour the high energy process. The Water Research Centre had reported flotation being particularly effective for the treatment of stored water containing heavy algal loads and for stored low turbidity, highly coloured water. A similar point also arose in the comparison of lagooning with centrifruging or sludge pressing in sludge disposal.

In conclusion, Mr Jeffery made a couple of general observations. Mr King in his opening address quoted the cost of energy in the industry as 6% of the whole. Capital charges, in the form of interest and depreciation accounted for about 50%. In his own Company, water treatment revenue costs amounted to 17% of total revenue expenditure and treatment energy costs were 2.92% of total treatment revenue costs. In other words, a 20% saving in water treatment energy costs would only reduce treatment costs by 0.6% and total revenue costs by 0.10%. Capital charges (interest and depreciation) represented 42% of the total revenue costs of water treatment while chemicals accounted for another 21%. Therefore consideration of treatment costs ought to start with capital charges. Except where energy costs were particularly high, as in the flotation system, it seemed that this would provide the main indication of the appropriate scheme. The water industry had probably been right, historically, to place most importance on capital costs, but perhaps this was changing as the real cost of energy increased: maybe the price of energy was not high enough now. In any event, 0.1% of total revenue costs of water supply was of the order of £1m a year for the industry as a whole. One factor which might affect the debate on high capital/low energy versus low capital/high energy schemes in future was current cost accounting. By increasing the revenue charge associated with high capital cost schemes, current cost accounting could move the balance towards low capital/high energy schemes. In what he had been saying, he had tried to be something of a 'devil's advocate' but he ended by stressing the almost moral importance which he felt must be attached to energy conservation in general, and to the optimum use of energy in the water industry in particular. He had looked at the index of the 1950 edition of IWE Manual of British Water Supply Practice and at the index of the 4th edition of the Manual published in 1969. Neither index included the heading 'energy'; he was grateful to the Institution for focusing attention on the subject through this symposium and to Mr Coates for his paper.

F. E. OLDROYD (North West Water Authority) supported previous speakers who had drawn attention to the wastage of energy associated with river regulation schemes. It should be fundamental to the design of water treatment plants that the raw water quality should be as high as possible and that plants were located so as to avoid unnecessary pumping. The author had not mentioned the energy savings which could be achieved in the filter backwashing operation for example by the use of a high level reservoir supplied by a small continuous flow pump to replace the conventional intermittent operation of a large in-line pump.

It was disappointing to read that the author did not recommend the flotation process on account of the relatively high use of energy. Although this was accepted, there were substantial savings in capital cost compared with alternatives especially when the cost of sludge disposal was included. The author appeared to consider chlorine and ozone as alternative disinfection processes. This was surprising in view of the considerable difference in production cost in favour of chlorine. It was doubtful whether consumer acceptability would require the disinfection process to be carried out using ozone.

In conclusion, he agreed with the author's comments on the complexity of the decision-taking process in the design of water treatment plants but offered a word of caution that in the pursuit of economies in energy use they did not lose sight of the prime objective, that of treating water effectively.

I.H. BENSTED (Thames Water Authority) said that the Water Industry could perhaps already claim to be one of the most accomplished exploiters, albeit indirectly, of solar energy. The lesson for the future was that in the circumstances there was a need to continue to search for ways of utilizing natural energy sources as effectively as possible. Mr Speed had already mentioned a specific example.

Energy saving in water treatment was largely a matter of making the best possible use of the head available at inlet: the client must however consider the whole system, including supply and distribution. Mr Coates had produced a valuable paper which dealt comprehensively with head loss economy through the treatment process. In addition choice of site, foundation levels, and planning constraints sometimes presented interesting problems with energy implications. Such considerations were a major factor in selection of upward flow primary filters for a recent major works in Thames.

The author was right to draw attention to the significance of overall costs, if capital, energy, and other operating costs were to receive their correct respective weightings in the financial appraisal of design options. If the benefits of competitive tendering were to be properly obtained by way of equal opportunity and precise specification, then the details of the method of evaluation must be incorporated into enquiry documents with performance based specifications. If the design were carried out in-house, similar principles applied in the selection of design options.

Where they were concerned with the best technique for producing a given output, the discount rate used in the water industry was normally 5%. The assumption currently suggested for electricity tariffs was an increase in real terms of 2½% a year from 1980 levels in a smooth path to the end of the century. Taken together with assumed lifespan, such parameters provided the basis of assessment. The analysis was, however, sensitive to the values ascribed. There did not appear to be justification or evidence to support either higher discount or energy inflation rates. Such appraisal could give differing results; some energy saving devices may be demonstrated not to be worthwhile as well as vice-versa. The objective was to be able to sort the wheat from the chaff in advance of commitment. The author's comments were invited.

With regard to process considerations, bankside storage was an important part of the treatment process for lowland river waters in Thames. Leaving aside possible pumping economies related to tariffs, deliberate reduction in top-water levels and generation of hydro-power, an important area of energy conservation could be found in the use of purposefully designed inlet jets to achieve vertical circulation, and prevent spring-time stratification in the reservoir. The operational cost was in the order of only 2 to 3% extra over that required to raise the river water against the reservoir head.

In his introduction Mr Coates mentioned slow sand filters. It must be remembered that the cost of chemical dosing, and of sludge disposal, including their respective energy components, were part of the equation when applicable. Use of ozone as a disinfecting agent probably represented an unnecessary use of energy, and was undesirable if significant levels of dissolved organic carbon were allowed to persist to the end of the treatment process. As an oxidizing agent earlier in the process, prior to biological treatment, ozone might produce real benefit, but it would be of interest to have from the author some idea of the energy costs associated, since they were likely to dominate other energy costs at a treatment works, apart from pumping.

High lift pumping usually accounted for 60-80% of the energy usage on a treatment works. Resort to gravity flow in tunnels, where this was feasible, might be one approach to energy conservation in high lift pumping. In London, for example, this approach to the necessary replacement of the ageing water main system was being adopted not only to conserve energy, otherwise dissipated in overcoming friction losses, but also to avoid high pressure surface mains which were a continual source of potential disruption of normal life in the streets above, and were subject to a high leakage rate.

H. RUNDLE (Severn-Trent Water Authority) referred to the use of gas recirculation for mixing of anaerobic digesters. In this system it was necessary to compress the digester gas and reinject it into the sludge. In any gas compression process as much as 70% of the electrical energy input might be wasted as heat. With a low speed paddle mixer system, however, the energy input might be converted much more efficiently. For example, a full scale digester with a capacity of about 400 m^3 was mixed efficiently by a paddle operating at about 20 rpm with a power input of less than 3 W/m^3 whereas gas recirculation mixing would require about 7.5 W/m^3.

He asked Mr Coates to comment on these figures.

Written discussion

M.J. McDONALD (Thames Water Authority) commented on the list of processes given on page 2(b) 4 as being contained in a typical water treatment plant. Would not significant energy savings be made if the stages of mixing and coagulation, flocculation, clarification, and sludge treatment were replaced by rapid gravity and slow sand filtration, still leaving a reliable and well-proven water treatment system? Any suggestion that slow sand filters were wasteful in the use of land could be disproved quickly, for it was not difficult to show that a set of modern high-rate slow sand filters with automated sand cleaning arrangements would not occupy a greater area for a given output than was required for plant using chemical processes. It was not unusual to find the considerable space occupied by sludge lagoons in the latter process to be omitted from area comparisons. Could the author give an indication of the amount of energy used in the production of the chemicals (other than chlorine) required in dosing the type of plant he advocated?

Author's reply to discussion

In response to Mr Jeffery, Mr Coates agreed that the particular method of comparing costs in tender adjudication was not of importance as long as it included the main 'flows' of costs (i.e. capital, maintenance, operating, chemicals, and energy): represented the most likely situation that could be expected (i.e. period of time to be considered, flow build-up, etc.), and was known to all parties through the tender documents.

The savings resulting from the alternative filter control system for the Anglian Water Authority plant were such that in 1973 prices the energy saving at half plant flow paid for the additional control equipment in two years and, in addition, the civil engineering costs were reduced by £20,000. The savings would be even more worthwhile with today's energy costs.

Mr Coates agreed that Mr Cash's suggestion that efficiency followed from plant automation was almost invariably true. In the case of water treatment plants, two key examples were: the ability to wash filters either when required by the process or at times of cheapest tariff, rather than be constrained to the day shift as in the case of many manual plants; and better optimization of chemicals with varying plant flow or water quality.

With regard to hydraulic mixers, Mr Coates agreed that it was imperative to design for turn-down conditions and he considered that this was achievable and was generally a preferable solution to using expensive variable energy input mixers. He confirmed that diffused air mixing was the most energy efficient, if an energy source had to be provided at the plant. But in his experience this was rarely necessary as surplus inlet head was so often available for spray or gravity methods.

The points made by Mr Jeffery and Mr Oldroyd concerning flotation exemplified Mr Coates's integration argument. The clarification versus flotation debate had to be settled on the basis of total costs across the various disciplines and time zones for each case being considered. There was absolutely no doubt that there were process problems that were treated best by flotation but the process worked effectively in many instances where it was not the optimum solution, if the true total costs of civil engineering, particularly of the additional flocculation tanks and energy consumption, were included. In each case these costs, together with the savings that accrued on some occasions from reduced chemicals and drier sludges had to be allowed for.

Mr Oldroyd had suggested energy savings could be made by using the constantly fed high level reservoir for filter washing. Although the author had been associated with plants where such a system was specified, he did not consider it a good solution. Additional capital costs were involved in the reservoir construction and the system lacked flexibility as washes could not be carried out in quick succession.

In response to Mr Oldroyd's and Mr Bensted's comments on ozone, the author made the following points. The use of ozone as an alternative to chlorine was normally associated with an intermediate stage of treatment. Although it would reduce the final chlorine requirement to give a residual to supply, it would not normally replace the final chlorine dosing equipment. The use of ozone for final disinfection was usually unsatisfactory because of the short duration of any residual. The system had found favour on the Continent where chlorine versus power costs had made it more viable but there would have to be very good process reasons for its adoption in the UK. The total energy consumption with ozone varied from 20 to 30 W/g of ozone and usage in potable water applications would be 0.4 to 1g/m^3 for colour and taste removal to as much as 5 g/m^3 for the oxydation of micropollutants.

Mr Bensted had stated that a discount rate of 5% and 2½% per annum increase in real energy costs were the figures currently used to determine which energy saving scheme should proceed. Mr Coates's personal view was that a fixed discount rate should not be used as this did not adjust adequately to the different types of capital investment. He would favour a higher rate being used for investments which were in rapidly advancing technologies as in these areas obsolescence would occur and technical developments reduce costs. The energy inflation figure he considered to be a little on the low side when considered against events of the last eight years.

In response to Mr Rundle's comments on energy used for mixing of digesters, Mr Coates stated that compared to Mr Rundle's figure of 7.5 W/m^3 for gas recirculation, Degremont normally installed a capacity of approximately 3.5 W/m^3 and a normal actual demand was 2.7 W/m^3. This also tied up with the findings of Noone and Brade that gas lift mixers power requirements seemed essentially 3 W/m^3 irrespective of digester scale (IWPC 1979: Anaerobic Sludge digestion - need it be expensive?). With regard to paddle mixers, Degremont had references with this system but would not recommend it for large digesters.

Mr MacDonald's points on slow sand filters were noted. Mr Coates considered that it was unlikely that where land was scarce a sludge lagooning solution would be used and that land cost and capital cost savings in his experience more than compensated for additional energy and chemical costs. However, in some instances, there were process reasons for installing slow sand filters, for example, the removal of colloidal silica.

In summary, Mr Coates repeated that there were no panaceas, indeed in a well-run industry like the water industry it would be a condemnation if there were. Nevertheless as energy costs increased, small savings became more worthwhile. They needed to be sensitive to the fact that waste could, and was, most likely to exist at boundaries and to try to discover how the total system could be optimized with highly cost effective integrating mechanisms. This was not easy to achieve as the differentiation, i.e. specialization, within boundaries, was a major source of innovation and efficiency and must not be stifled. The challenge was to get the best of both worlds, the benefit of specialized expertise, without the lack of understanding so common in today's world.

3 ENERGY USE IN SEWERAGE AND SEWAGE TREATMENT

By J.M. HASELDINE, MA, FICE, FIMechE, FIWES*

INTRODUCTION

The subject of energy use and conservation in sewage treatment is one which has received a lot of attention in recent years. Some of the more important and useful contributions are Martin and Spencer (1), Clough (2) and (3) and Thompson and Larkin (4).

Sewerage and sewage treatment have always tended to be the poor relation in the overall water cycle largely because there is practically no end product worth selling and the costs have to be borne by ratepayers.

Water supply is in a somewhat better position because everyone recognises immediately that water is essential and generally speaking everyone, including industry, is prepared to pay a proper price for something which is delivered to them and which they use on a daily basis.

Because no-one likes spending money on the disposal of wastewater, the industry has always been very cost conscious, both from the point of view of capital expenditure and running expenses, and because of this energy consumption has never been higher than strictly necessary.

Both sewerage and sewage treatment are basically natural processes and given the right conditions, so that maximum advantage can be taken of nature, then very little, if any, energy is required. Take for example a sewerage system for a seaside town; if the ground contours are right and there is no development at sea level, then a system of sewers can be arranged to discharge through a sea outfall and the only energy required would be to operate the screening or other pre-treatment process.

Similarly in some countries such as the Middle East, sewage treatment can be by stabilisation ponds where the only energy used would be in pumping the sewage into the ponds and the entire treatment process occurs naturally making use of the abundant sunlight.

This paper describes in general terms the areas where energy is used in sewerage and sewage treatment and indicates how savings in energy consumption might be made. However, the savings are likely to be marginal and care must be exercised to ensure that any savings made are not detrimental to the satisfactory operation of the system.

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* Senior Partner, John Taylor & Sons

SEWERAGE

For the conventional water-borne sanitation system there has not so far been any practical alternative to the gravity sewer.

Discharges of water-borne wastes from domestic properties are intermittent and very variable in quality. For many hours of the day there is no flow at all, then there could be a steady flow of almost pure water from a bath or a sudden flush from a water closet or flow from the kitchen sink containing potato peelings and considerable quantities of earth and grit.

Such variable discharges can only be accommodated in a reasonably sized pipe and 100 mm diameter is the standard adopted for domestic properties - this is very different from the standard 12 mm diameter domestic water supply service pipe.

The house connection discharges into the street sewer and the smallest size for this is 150 mm diameter.

In a properly designed and maintained sewerage system, the sewers will never run full, and in dry weather, even at maximum day time flow the depth of liquid in the sewer is unlikely to be much more than one third of the pipe diameter.

In order that the sewage will flow down the sewer, the pipes have to be laid to a gradient and the minimum permissible gradient is determined so that when the sewer is full (or half full) the velocity is 0.9 m/sec.

If the area to be sewered is sloping or undulating then usually a route can be found for the sewers such that they can be laid at reasonable depths and gradients which are steeper than or equal to the minimum permissible. However, if the ground is flat then the sewer will get deeper and deeper and eventually it will be so deep that it is too difficult and expensive to construct and it is then necessary to construct a pumping station to pump the sewage either direct to the sewage treatment works or to the head of the next length of sewer.

It is only when conditions are such that pumping stations are required in the sewerage system that energy is used. It is clear that if the total number of pumping stations, and the pumping head, can be reduced then energy will be saved.

The only way this can be achieved is to lay the sewers at flatter gradients and this immediately calls into question the way in which the minimum gradient is calculated.

The first question is whether the figure of 0.9 m/sec for the minimum velocity is correct. Expressed in the metric system as 0.9 it sounds a reasonably accurate, well thought-out figure, but in the Imperial system it was 3 ft/sec which has all the indications of being a *good guess* and a nice round number.

The second question relates to the calculation that has to be made to determine the minimum gradient required in order that this velocity can be achieved. A number of formulae are in general use all of which produce different answers over quite a wide range. The formula generally accepted as the most accurate is the Colebrook-White formula and the Hydraulics Research Station (5) have produced easy to use charts based on this but here again one comes up against a difficulty in that the user has to select a value for the roughness factor 'k'. Different values of 'k' produce different answers, which is right?

Hydraulics Research Station (6) have recently done some experiments to determine head losses in sewage pumping mains but conditions in a pumping main are not necessarily the same as conditions in a sewer.

Any research on the physical properties of sewage is difficult since it is impossible to define sewage. A sample of sewage can be taken from a particular place and analysed and defined. If a second sample is taken from that place it will be different. If the same first sample is mixed thoroughly and divided into two equal samples, one of which is analysed immediately and the other some hours later, the results will be different.

It can thus be seen that experimenting on the hydraulic properties of sewers is a difficult and imprecise exercise. Nevertheless, a case can be made out to carry out some research to examine the performance of existing sewerage systems, with a view to verifying the minimum velocity requirement and the correct 'k' value.

Having said all this, however, it must be acknowledged that the effects on energy consumption in sewerage systems would only be marginal. Perhaps pumping stations could be slightly shallower or fewer in number, if sewers could be laid flatter. There would, however, be significant savings in capital cost.

If the researchers were to come to the conclusion that sewers could be laid flatter than at present, they would have to produce some very convincing evidence since no-one would be prepared to take any risk that the system he was designing might be subject to frequent blockages.

SEWAGE PUMPING

Pumping stations are an integral part of most sewerage systems since it is unusual for the ground contours to be such that the whole area can be served by gravity sewers feeding direct into a sewage treatment works built at ground level.

Pumping stations are certainly considerable energy users. To lift 5 megalitres per day through 10 metres uses say 250 kWhs of electricity. To treat 5 megalitres per day of average sewage by the aeration process to normal standards uses 500 kWhs.

The design of sewage pumping stations is very different from the design of water supply pumping systems. Generally speaking water supply pumping systems operate for long periods at constant head and quantity. Again, in general, the static head is large and the pipe friction is small in comparison.

Sewage pumping systems on the other hand have to deal with a very wide range of flow rates from less than half the average daily rates to up to six times that average rate. Also, the static head is often only about 10 metres or less and is rarely more than 20 metres so that pipe friction is a significant proportion of the total pumping head.

Sewage pumps have to be able to handle solid matter and in particular must be able to pump paper, rags and plastic material without choking. Pumps capable of achieving this are not nearly as efficient as clean water pumps of the same duty. In fact, good hydraulic efficiency can often lead to frequent blockages, particularly on pumps handling large quantities.

For small quantities pumps are of the pure centrifugal type of low specific speed. The flow pattern of the liquid through this type of pump is turbulent and this prevents rags from accumulating on the leading edges of the impeller. For larger quantities, bearing in mind that the overall head is low, the type of pump required is a mixed flow pump tending towards axial flow with high specific speed. In an axial flow pump the flow pattern is streamline and if rag gets draped over the leading edge of the impeller, it will stay there and pump blockage will occur.

Because of the wide variation in flow rates that have to be handled, sewage pumps usually operate on an intermittent basis. For very small quantities, there is usually just one duty pump capable of pumping the maximum flow of 6 x dwf. When this pump has drawn the liquid in the sump down to the lowest level it will stop and it will not start again till the sump has refilled. The selection of the right type of pump for this duty is not too difficult as the pipe friction head can be determined with reasonable accuracy.

For larger flows it is advisable to have two or more duty pumps operating in parallel to handle the peak flows and it is in this type of station that difficulties occur in selecting the best pump duties. Under average flow conditions, only one pump will be operating and the friction in the rising main will be low. If the pump is designed to operate efficiently running by itself, then it may not be at best efficiency when a second pump is working in parallel due to the increased pipe friction. On the other hand, if the pump is designed for the peak flow conditions, it may be very inefficient when operating by itself. Sometimes it is advisable to have two-speed motors to get over this problem.

What then is the scope for energy saving in sewage pumping?

The first and obvious point is to ensure that infiltration into the sewerage system is as low as possible. This is easier said than done. It is very difficult to identify points of leakage into a sewerage system and very expensive to repair them.

The most promising approach, though the savings may only be marginal, is to examine carefully the operating criteria for the pumps and to ensure that the stop and start sump levels are selected correctly. There is no reason why sumps should not be allowed to fill up to the soffit level of the incoming sewer, or even marginally above, thus reducing the overall pumping head when the pump begins to operate.

SEWAGE TREATMENT

As stated earlier, sewage treatment is essentially a natural process and if given the right conditions, requires very little energy. It is only when the right conditions are not available, or it is unreasonably expensive to provide those conditions, that energy is used in any great quantity.

The sewage treatment process can be divided into four main stages as follows:

(a) Preliminary treatment to remove grit and either to remove or macerate large solids.

(b) Sedimentation to remove all settleable solid matter in the form of sludge.

(c) Biological treatment to oxidise colloidal and dissolved impurities.

This process almost invariably involves a final sedimentation stage to settle out the secondary sludges formed during the oxidation process.

(d) Sludge treatment and disposal.

Occasionally, when very high standards are required for the effluent, a further treatment stage is necessary to reduce the suspended solids and sometimes the ammonia to very low levels.

Sewage treatment first became necessary when the industrial revolution resulted in the growth of large urban communities. At this time the only convenient form of energy available was the coal fired steam engine and the only application to sewage treatment was in pumping, all other operations being manual.

The earliest sewage treatment process to be developed was land irrigation. It was very effective, used no energy other than energy required to cultivate the land, and is still operated in some places today.

To be effective, however, very large areas of land are required and nearly all developments in sewage treatment technology have had the objective of reducing the area of land required but at the expense of requiring considerable quantities of energy to ensure that the sewage can absorb the required amount of oxygen which, in the land treatment process, it would absorb naturally from the atmosphere.

Preliminary Treatment Processes

In a modern sewage works, energy is used in the preliminary treatment and in the sedimentation stages but this energy is primarily used to replace manual labour rather than as an essential part of the treatment process.

For example, in early treatment plants, large solids were removed on bar screens that were raked by hand. In order to reduce manpower requirements, mechanical raking was introduced. Similarly, early designs of sedimentation tanks required the tank to be emptied at regular intervals and the sludge was then scraped by hand to the sludge withdrawal outlet. Modern works have mechanical scrapers which can sweep the sludge to the sludge outlet hopper without emptying the tank and the sludge can be withdrawn as necessary.

The energy consumed in preliminary treatment processes and sedimentation tanks is not great and there is little scope for economy. Any economies that can be made would probably result in a requirement for more manual labour.

Biological Filtration

It is in the biological treatment processes that considerable amounts of energy may be used and where significant savings might be achieved.

The first successful method of biological treatment was the percolating or trickling filter. Provided there is an adequate head differential between the incoming sewer and the point of discharge (4 metres is probably sufficient) the sewage will gravitate through the works and there will be enough head to operate the distributors which are required to spread the flow evenly over the filter media. For circular beds, the reaction from the jets issuing from the filter arms is sufficient to rotate the arms and for rectangular beds the distributor can be driven by means of water-wheels.

In recent years, particularly on large works with rectangular filter beds, the distributors have been mechanically driven to ensure more even distribution of the sewage over the media at varying rates of flow and to make it possible to design the works with the minimum loss of hydraulic head. The energy requirement for this is quite low and it is unlikely that conversion of mechanically driven equipment to water power would be possible due to inadequate hydraulic head being available.

Activated Sludge Treatment

Although percolating filters give rise to a much more compact sewage treatment plant than the original land treatment, they still occupy a large area and are expensive to construct. It would be difficult to visualise a really large sewage treatment works such as Beckton or Crossness with percolating filters instead of the activated sludge process.

The essence of the biological treatment process is to ensure that there is sufficient oxygen always available to enable bacteria and other living organisms to flourish and to feed on the colloidal and dissolved impurities in the sewage. In percolating filters the organisms live on the surface of the media and they obtain oxygen from the air which is in the voids between the solid material. For good results it is essential that percolating filters are properly ventilated.

In the activated sludge process, the sewage is retained in tanks and oxygen is introduced by mechanical means. The bacteria and other organisms that do the purification develop as a light flocculent sludge which settles out in the final sedimentation tanks, is withdrawn and circulated back through the aeration tank. The area of land required to treat a given quantity of sewage by the activated sludge process is considerably less than the area required for treatment by percolating filters and the capital cost is also less. This is why all really large works use this process.

There are two fundamentally different methods for introducing the necessary oxygen into activated sludge tanks. The first is to compress air to sufficient pressure so that it can flow through a system of pipes and porous domes laid on the floor of the tanks. The air escapes in fine bubbles which work their way up through the sewage to the surface, thus making oxygen available. This is the diffused air process.

The second method is surface aeration. In this method rotating impellers are mounted at the liquid surface and these cause rapid circulation of the contents of the tank so that liquid at the bottom is drawn up to the surface and is then sprayed outwards through the air before falling back into the main body of liquid.

Manufacturers of the different types of plant will claim that their particular equipment is the most efficient. In practice there is very little to choose and it is doubtful whether diffused air is more efficient than surface aeration or vice versa. With both systems, however, the operator has some degree of control over the amount of power that is absorbed by the plant.

There are a number of variations of the activated sludge process which concern the flow pattern and retention time both of the mixed liquor and the returned activated sludge. They all have their merits for particular circumstances but none shows any outstanding energy saving for any given standard of treatment.

Potential energy savings are possible by controlling the dissolved oxygen levels in the aeration tank. The variable quantity and quality of the sewage is such that the oxygen demand fluctuates. By trying to match oxygen input, as reflected by dissolved oxygen levels, to oxygen demand, energy saving may be possible.

However, this saving is limited as a minimum power input is always required to ensure adequate mixing, and at times of high oxygen demand, more energy would be used than if no dissolved oxygen control were practised.

Overall, though, and especially in low flow periods, some energy saving should be possible.

Mention must be made of the recent development for using pure oxygen in the activated sludge process rather than air. It is claimed that by using pure oxygen the retention time for treatment can be reduced and, therefore, construction costs and the area of land to be used would be less than in the case of the conventional activated sludge process. However, considerable energy is required to produce pure oxygen and overall it is unlikely that the pure oxygen treatment process would show any significant reduction in total energy requirements. In the author's view it is unlikely that major sewage treatment works will be designed using pure oxygen and the only way this process can be useful is in increasing the capacity of existing works when extensions are difficult or impossible to construct due to lack of space.

Sludge Treatment and Disposal

Sludge treatment and disposal has always been, and is likely to remain, the most difficult part of the sewage treatment process. The problem lies in the difficulty of dewatering to produce a dry final sludge.

Of the sludge treatment processes the one which has stood the test of time and which is used on nearly all major works is the heated anaerobic digestion process. In this process the sludge is warmed to a temperature of about 30°C and is retained in the sludge digestion tank for a period of three to four weeks during which time an anaerobic decomposition takes place. Approximately 30% of the dry solid matter in the sludge is destroyed in the process and methane is generated which can be collected and stored in a gasholder and used as an energy source. On small works the methane is used in gas fired boilers for heating the sludge and keeping the contents of the digestion tank at the correct temperature. On larger works it is economic to use methane in dual fuel diesel engines for generating electric power for use in the works and the cooling water required by the dual fuel engines is then used to heat the sludge and maintain correct temperature in the digestion tanks.

Normally it is not considered necessary to insulate sludge digestion tanks to prevent excess heat losses. If there is no power generation at the sewage works then there is usually sufficient methane generated to maintain the correct temperature in the sludge except under very severe winter conditions when augmentation by oil fired boilers may be necessary for short periods.

At works where the methane is used for power generation then the heat obtained from the dual fuel engine cooling water is not sufficient to maintain temperatures in the digestion tanks during the winter time and topping up is necessary by burning some methane direct in boilers for this purpose.

It is interesting to note that Severn-Trent Water Authority have recently provided insulation to their sludge digestion tanks at Minworth which has reduced the amount of methane that has to be used for direct heating and has made a substantial increase in the amount of power generated by the dual fuel generators. The output of locally generated electricity has almost doubled thus reducing the electricity bill very substantially.

Another factor in achieving this saving at Minworth has been the care and attention given to thickening the sludge as much as possible before introducing it into the sludge digestion process thus reducing the total volume of liquid to be heated.

Sludge digestion is only a treatment process and the residue is still awkward to deal with. The most economical way of disposing of sludge is to take it in liquid form either by tanker lorry or direct by pipeline and to spread it on agricultural land or dump it at sea. If these methods of disposal are not possible then there are a number of methods available for dewatering sludge but all of them use considerable quantities of energy and furthermore the majority require conditioning of the sludge by the addition of chemicals which in turn require energy to produce.

Substantial savings in energy used for sludge treatment and disposal can be made by ensuring that the sludge drawn from the works is at thick as possible. If the moisture content of sludge entering a sludge treatment process such as digestion can be reduced from 97% water to 94% water then the volume to be treated is halved giving rise to savings in heat requirements and transportation costs to the point of final disposal.

Preliminary thickening is also beneficial when sludge treatment is by conditioning and some method of mechanical dewatering such as belt or filter processes are used. There are savings in power required to operate the process due to the reduction in volume to be handled and also savings in the amount of chemicals that are needed for conditioning.

NEW PROCESSES

From time to time new sewage treatment processes are announced but generally speaking on investigation they turn out to be variations of existing processes and again in general they tend to consume considerable quantities of energy.

Great interest was shown a few years ago in the possibility of physical-chemical treatment processes and a large experimental plant was built at Coleshill to carry out research on this. Research still continues but the indications are that it is unlikely that physical-chemical treatment will ever supersede conventional sewage treatment processes.

In the gradual development of sewage treatment over the last 150 years the tendency has been to reduce capital cost of construction but to increase the use of energy. Where energy is used to replace manpower such as in the automatic scraping of sedimentation tanks or in the preliminary sewage treatment processes its use is justified and in spite of the present energy crisis it seems unlikely that any designer of a new sewage treatment plant in this country will design a works which is manpower intensive for operation, though this may not apply to the design of works overseas in underdeveloped countries.

There are two new processes which are of considerable interest since they would appear to be a real step forward in sewage treatment technology and both are economical in the use of energy. The first is the deep shaft aeration process. Actual cost of construction is high and geological considerations are important, since to be effective the shaft has to be constructed to a depth of 50 m or more. The deep shaft process is essentially a diffused air aeration system but the efficiency of the process is improved by the fact that the air which is introduced into the shaft is carried down to the bottom and the very high pressures at this depth ensure that all the oxygen in the air is absorbed into the sewage.

The second development which would appear to have considerable potential is the rotating biological contactor. This system is a combination of the biological filtration process and the activated sludge process. A series of discs up to 3 m diameter and made of suitably shaped plastic material are mounted on a horizontal shaft which is located just above top water level in the treatment tank. The shaft is rotated slowly either by direct electric drive or alternatively by buoyancy using air injected into the tank underneath one side of the shaft. The slow rotation of the discs first passing through the liquid and then through the air and then back into the liquid again encourages the rapid development of biological growth on the discs and it is this biological growth which treats the sewage.

There are several plants in America dealing with populations in excess of 100,000 and they are even more compact then conventional activated sludge processes. One advantage of this method of treatment is that economies can be made in the size of the primary sedimentation tanks as it is only necessary to remove very coarse solids.

Mention should also be made of fluidised bed techniques which are still in the development stage and treatment can be either aerobic or anaerobic.

The aerobic fluidised bed process is based on the activated sludge principle. Air or oxygen has to be introduced to the bed and though the plant is more compact than a conventional activated sludge plant, it is doubtful whether there would be a significant saving in energy.

The anaerobic fluidised bed technique for sewage treatment has so far only been tested on a pilot plant scale in America by W.J. Jewell (7). The only energy used is for recirculation through the bed and methane is produced. If this process can be developed to full scale, then there would be a substantial saving in energy compared with activated sludge treatment.

EFFLUENT STANDARDS

If a real attempt is to be made to save energy on sewage treatment then one of the first things to examine is whether the standard set for the effluent discharge is appropriate to that discharge and the characteristics of the receiving water.

The next thing to examine is whether the works is being operated in such a way that the standard is being achieved with a proper margin of safety or whether it is being operated taking full advantage of all the resources available and is producing an effluent which is of an unnecessarily high quality.

There is a natural tendency for sewage works operators to try to produce the best quality effluent possible at all times but this can be wasteful in energy use if the receiving waters can absorb a less stringent quality of effluent without detriment. It should not be forgotten that self-purification will take place in the receiving waters provided conditions are satisfactory and there is no point in using energy in a sewage treatment works to perform a function which will occur naturally.

Sometimes standards are set which limit the amount of ammonia in the effluent and to achieve this in the activated sludge process it is necessary to have long retention times. To obtain a fully nitrified effluent something like 2½ times the amount of power is required compared with an aeration process which will satisfy the normal 30 mg/l suspended solids and 20 mg/l BOD standards without nitrifying the ammonia.

The selection of the correct standard for a sewage effluent is not easy and one factor in particular which must be borne in mind is to ensure that the sewage treatment works can operate reliably to produce that standard. It so happens that the conventional 30/20 standard for effluent means that the works is operating under stable conditions and can cope with fairly substantial variations in quality and quantity without affecting the effluent standard to any great extent. It is sometimes thought that if a standard of 60 mg/l of suspended solids and 40 of BOD is set there will be considerable savings in the cost of constructing and operating the sewage treatment works but this is not the case. A works that is designed to this standard will tend to be unstable in operation and will not be able to cope with fluctuations in quality and quantity of the incoming sewage. If such a standard is set for a works it is normal practice to by-pass a proportion of the sedimentation tank effluent so that the remainder is given full treatment through the biological treatment plant and to blend the two effluents before discharging to the outfall. Since the BOD of a sedimentation tank effluent is about 160 mg/l it can be seen that only 1/7th of the flow can be by-passed and so the saving in construction and running costs is less than 15%.

It should also be remembered that an activated sludge plant which is only nitrifying part of the ammonia in the sewage is operating in an unstable manner and is liable to be upset by changes in quality or quantity of the sewage or by temperature changes. Standards set for activated sludge plants should either require full nitrification of ammonia or no nitrification at all. Partial nitrification, although energy saving, cannot be reliably maintained.

CONCLUSION

Sewerage and sewage treatment have never been large users of energy and it is unlikely that anything more than marginal economies in energy use can be made, particularly on sewage pumping and on those parts of a sewage treatment works where energy is used instead of manpower. If economies are attempted on these two aspects, then they might well prove to be counterproductive as they could cause blockages in pipelines and other parts of the system.

On biological treatment, there is scope for energy saving on activated sludge plants, but care must be taken to ensure that the plant is operating in a stable mode.

Sludge treatment and disposal, if highly mechanised, can use large quantities of energy. In recent years there have been several heat treatment plants that have been closed down to save energy. Thickening of the sludge before it enters the sludge treatment process is probably the most important way in which energy can be saved.

Finally, efflvent standards should be examined critically, should not be unnecessarily stringent and should be set to suit the circumstances of the receiving water.

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DISCUSSION

Author's introduction

Mr Haseldine in introducing the paper said that the title finally selected was different from the title originally proposed and printed in the programme. The reason for this as explained in the paper was that with very few exceptions modern trends in sewage treatment were generally directed towards the use of more energy in order to save labour and use of land.

On the subject of pumping, Mr Haseldine quoted a case where pumps had been selected on the basis of efficiency but when installed frequent blockages due to ragging-up had occurred. Eventually the manufacturers had recommended cutting back the leading edges of the impellers. This cured the ragging-up problems but resulted in slightly less efficiency for the pumps. The problem of pump blockage was not necessarily one of the clear space through the impeller but was more concerned with the flow pattern through the pump.

Mr Haseldine then said that with the present organization of the water industry the Regional Water Authorities were now responsible for both setting standards and for constructing works to meet these standards. Before reorganization in 1974 standards were set by one authority and had to be achieved by others and Mr Haseldine cited a case where an unnecessarily high standard had been set which would have led to the expenditure of considerable sums of capital and energy use in perpetuity which were completely unjustified.

In conclusion Mr Haseldine said that for sewage treatment reliability was all important. High efficiency of plant did not always lead to reliable operation.

Verbal discussion

B.H. ROFE (Rofe, Kennard & Lapworth) noted that the selection of minimum velocity and the hydraulic roughness factor for the design of a sewer had been the subject of continuing research for a number of years. Recent work carried out, and still in progress, at the Hydraulic Research Station, had established that the sliming process in foul sewers (including pumping mains) went through continuous cycles of build-up/slough-off of deposits, and was much less dependent on the type of pipe used than some manufacturers would have the users believe! The 'k' values put forward in the latest set of HRS Charts, reflected the preliminary findings from this research, and would no doubt be reviewed in due course as further understanding was gained.

A recent paper put forward by HRS to the Hydraulic Sub-Committee of the Standing Technical Committee on Sewers and Water Mains, confirmed the author's view that the Colebrook-White formula was the only satisfactory one to use throughout the range of flows and pipe sizes: in chart form, and with the different factors easily put in a simple computer programme, it was now easy to apply. The formulas devised by Crimp and Bruges, Hazen-Williams and others only applied within narrow ranges of pipe sizes and flows and could seriously mislead outside the ranges; they might still be useful for quick preliminary assessment but must be used with care.

Mr Rofe then put in a plea that there would be some exceptions from the author's 'no-one' who would be prepared to lay flatter sewers in the course of service. Maybe someone could come forward who had experimented successfully or otherwise in this respect?

In respect of sewage pumping the author had highlighted the two important aspects of pump selection and control of leakage in regard to energy savings. On pump selection it should be noted that considerable savings could be achieved by controlling pumping to a rule curve based on a programmed micro-processor predicting inflow, and further work was now in hand at WRC to evaluate this aspect. Another factor which could help to reduce pumping costs would be the injection of polymers: did the author consider that this could lead to useful savings?

In regard to leakage control, it should be emphasized that modern methods of leak detection, and renovation and renewal of sewers, should enable considerable reductions to be achieved in infiltration, with consequent savings in the energy required for pumping and treatment.

On the energy requirements for sewage treatment, the author referred to the paper by Martin and Spencer (1) which had included some interesting figures comparing energy consumptions for alternative forms of sewage treatment. A later paper by Boche and Saraf (IPHE 1978), had criticized their conclusions in respect to land assessments, but had not, in his view, invalidated the main findings. In most cases it could be shown that selection of a scheme on the lowest energy budget criteria often led to greater capital costs. This line of thought had not been taken forward but surely it should be. Obviously the present economic troubles led to short-term economics but it must be recognized that they were short-term and short-sighted. Responsible engineers and scientists should look ahead and lead, not be mastered by short-sighted financial policies. They should be guided by the energy consumption in real terms, not in artificial financial figures.

In controlling the oxygen input for activated sludge or extended aeration processes, did the author consider that useful savings would be achieved by the inclusion of microprocessor controls? The technology was available and already applied under laboratory conditions; could this be transmitted into the field? A prototype study was already under way on maintaining balanced flow control. Did he see any advantage in terms of energy consumption?

The CIRIA optimization model was now being developed as a working tool and could be applied to analyse the design of existing treatment works. On many occasions it could be shown that only part of an existing works was overloaded so that small additions improved the overall system which had previously been under-used, thus producing a saving in overall energy.

R.W. BAYLEY (Water Research Centre) drew attention to the quite modest energy requirements that were involved in the established biological waste water treatment processes. He took as an example the values that had been reported by Martin and Spencer (1). If the energy required to build and operate secondary biological treatment facilities over a period of say 30 years was expressed in terms of a quantity of heat per day per head of population served then the energy required for the activated sludge system was equivalent to the heat consumed in boiling sufficient water for five to six cups of tea, and a mere two to three cups for biological filtration plant! He saw this as a clear demonstration of the high standard of professional skill in the engineers and scientists who had brought sewage treatment processes to their current state of efficiency. However, these current standards of performance were not to be seen as justification for complacency; indeed, energy conservation, on a national scale, would probably involve many sectors where the challenge would be found in making further improvements in what was apparently already an efficient practice.

Turning again to the paper by Martin and Spencer, Mr Bayley showed that as a consequence of the increases in real costs for energy the scales might be tipped still further in favour of biological filtration processes. If the price for energy increased annually at a real rate of more than 3.5% then biological filters would not only have an edge on activated sludge in terms of energy consumption but there would also be an economic justification for selecting filters! With this example in mind Mr Bayley wondered if the speaker expected to see a significant swing towards the installation of biological filtration plants in the remainder of this century?

In conclusion he reminded those present that members of the Institution were in the business of specifying, designing, building, and operating facilities that were likely to be in use for thirty to fifty years or more. The selection of the most appropriate schemes clearly involved the computation of present and future expenditures. Against a background of rising real costs for energy how was the engineer to proceed in his assessment of technically feasible alternative schemes?

H. RUNDLE (Severn-Trent Water Authority) said that the Lower Trent Division of the Severn-Trent Water Authority served a population of some 1.3 million people and the expected expenditure on 'power' for 1980-81 was £3m, of which about 40% was for sewage pumping and treatment. The per capita expenditure of £2.3 per annum was not large, but because of the total magnitude of the expenditure overall savings were worth making. In order to obtain useful savings in the sewage treatment processes close attention to detail by Operations managers was required. He considered that by far the most important influence on power consumption in sewage pumping was the standard of electrical and mechanical maintenance of the pumping equipment. In these days of reductions in manpower and revenue expenditure it was all too easy to cut 'obvious' expenditure on maintenance while less obvious cost penalties due to the inefficient operation of poorly maintained equipment were accepted.

With regard to the section on biological filtration systems, Mr Rundle said that the greatest factor which affected energy consumption in this process was the use of recirculation, and this normally required the pumping of a volume of final effluent at least equivalent to the total flow to the works. All of the available mathematical models of the biological filtration process predicted that, provided the surface of the media was efficiently wetted, recirculation caused a deterioration in effluent quality. It therefore seemed most likely that the effect of recirculation was to control the distribution of film growth within the bed and thus prevent ponding, but despite the fact that film growth varied throughout the year, recirculation was often applied in 'blanket' fashion without any control being exercized. In this respect, he wondered if there was a case for the use of more refined methods of recirculation control.

Bearing in mind that aeration was the largest user of energy it was interesting to note the work reported by Crabtree and Wood (1979, Wat. Pollut. Cont., 78, 27) which showed that oxygenation efficiency of a surface aerator and a blown air aerator when operated in combination was greater than that of aerators operated independently. Mr Rundle also pointed out that modification of the activated sludge process to include an anoxic zone would enable some of the energy used in providing for nitrification to be recovered.

As the loading on an aeration plant was increased the oxygen requirement (and hence the power consumption) per unit mass of BOD removed fell (e.g. Vosloo, 1973, Wat. Pollut. Cont., 72, 209) and the penalty was the larger volumes of often unstable surplus activated sludge which had to be treated. Mr Rundle asked Mr Haseldine for his thoughts on the ideal loading for an activated sludge plant from an energy conservation point of view.

The paper had rightly stressed the importance of sludge thickening in reducing digester heat requirements, and insulation of roofs at Minworth was also mentioned. He wondered if, in view of the fact that many digesters had floors which were located below ground water level, heat losses to ground water were significant and whether it was worthwhile also insulating digester floors in these circumstances. He asked the author to comment on this point.

C. MARTIN (L.G. Mouchel & Partners) noted the kind comments made by Mr Haseldine and other contributors to this discussion in referring to the paper which he had written in conjunction with Peter Spencer (1). He suggested that members might care to return to the original paper which had considered the problem of world energy usage and supply. It had made the point that fossil fuels were being used at an alarming and increasing rate and that they were finite in extent. Furthermore, even if adequate substitutes could be found, e.g. nuclear energy, there was a limit to the amount of energy man could use before he created environmental problems for himself. This was probably 1% of the total solar energy reaching the earth, so that in the distant future only energy derived from the sun could safely be used in increasing quantities. This implied solar power, wave energy, and wind power.

The paper had considered the situation where there were two or more satisfactory solutions to a problem and where a choice had to be made between them. In terms of sewage treatment, this often came down to a choice between low capital cost and high running cost, or vice versa. The available methods of financial analysis were not adequate to form the basis of choice for works which would operate for 30, 40, or 50 years, since funding of capital and costs of energy were subjected to arbitrary decisions. Who would have predicted a few years ago inflation rates of 20 to 25%? Who really believed now that inflation would fall to 5% in 1981? It was better to make a choice on absolute units not subject to arbitrary variation. The paper had considered the total energy content of any scheme and had drawn up a balance of energy use in construction plus energy use in running and recommended that the choice with the smallest total energy should be selected.

Two examples had been analysed, the first of a biological filtration plant as compared with an activated sludge plant. For this the basic data were sound and the result strongly favoured the biological filtration plant. The second compared two alternatives for pumping, either via pumping mains laid in tunnel with a low static head, or pumping mains laid in open cut with a high head. Here the data were not so sound. The initial analyses showed that the tunnel scheme was favoured, and in fact this was the scheme which was being constructed. With the co-operation of the tunnelling contractors, measurements were being made of the total energy input going into the construction, and when these data were available, which will be around the middle of 1982, it was proposed to repeat the analysis and to publish the results. Mr Martin expressed the hope that the final result would be the same as the initial one.

An energy balance had been drawn for activated sludge compared with biological filtration treatment. The prima facie examination showed that oxygen would be less economic than using natural air. An analysis had not been made of the deep shaft method or the rotating biological contactor but they would appear to be worthy of consideration.

Turning to sewage pumping, Mr Martin referred to work being undertaken by his company at Weymouth. They had produced a scheme for controlling a pumping station by minicomputer to enable it to run at least cost by utilizing available storage to the maximum and by the use of an optimization routine to make the most favourable pump selection. The optimization routine had been developed in general terms by Martin and King in conjunction with the National Physical Laboratory, and the particular algorithm for Weymouth had been developed by Dr Graham Evans at WRC, and was now running in simulation on the minicomputer provided for the pumping station.

They had also examined the problems of ground water and sea water infiltration into a sewerage system, and the preliminary conclusion from that investigation was that the cost of removing or preventing infiltration in an existing system was very high, and was not justified in the particular example considered by the savings in running, energy, and cost.

J.M. DAVIS (Water Research Centre) gave more details of the Water Research Centre's real-time sewage pumping optimization program which had been mentioned by Mr Martin. This real-time control program reduced energy costs of pumping sewage by exploiting storage of the wetwell and sewer system to reduce the frequency of operation of large pumps.

Friction losses in a rising main from a pumping station would be approximately proportional to the square of flow rate and hence the cost per cubic metre of sewage pumped at high rates exceeded that of sewage pumped at low rates. In its real-time version the program, installed in a mini- or micro-computer at the station, drew on a forecast of flow to the station derived from telemetered rainfall and a catchment model together with knowledge of the daily pattern of foul sewage flow. High forecast flows could be met with the use of a small pump starting early rather than with a large pump starting under electrode depth control when conditions were already critical. By the same token larger pumps might be turned off when the flow forecast indicated that the crisis had passed, even though wetwell levels might still be rising. The program also sought to distribute electrical demand over separate maximum demand metering periods thereby reducing the financial cost of using given quantities of energy by an Electricity Board.

The simulation version of the program might be used to design pumping stations with either optimization or electrode control and could indicate substantial savings in installed capacity not only with optimization control but also with electrode control when electrode depths were appropriately adjusted.

The programwas to be installed in Wessex Water Authority's new Radipole Lake pumping station in Weymouth, Dorset. L.G. Mouchel and Partners Ltd., the engineering consultants to WWA for this scheme, had derived a unit hydrograph for the contributing catchment and this was to be used as the basis of the flow-forecasting model.

J.G. PENNINGTON (Wessex Water Authority) commented on the selection of plant for pumping stations which were required to deal with high flows. He referred to the difficulties outlined by the author in selecting suitable pumps which would enable low flows to be dealt with by one pump, and peak flows to be handled by two or more pumps operating in parallel. Because of the increased friction head at the higher flows, this form of operation usually meant that at one or more of the pumping combinations, pumps would not be operating at best efficiency, and he referred to installations where six pumps running in parallel were used to deal with peak flows.

He agreed with the author that in some instances it was possible to overcome the problem by using two speed motors, and suggested that the use of variable speed drives offered even more opportunities to maintain the pumps at their best efficiency points against varying duty requirements. He also commented on the higher efficiencies which sometimes could be obtained from the larger pumping units, and how multi-speed or variable speed drives could be used to advantage. In some instances, by using multi or variable speed drives, the range of pumping duties could be met by a fewer number of pumps than would be the case if single speed drives were used. Each individual multi or variable speed pump could be designed to deal with a higher maximum flow rate than each individual single speed unit. Advantage could then be taken of the larger pumps to improve overall operating efficiency.

W.J.F. RAY (Thames Water Authority) referred to the author's comments on new processes, including deep shaft, activated sludge, and rotating biological contactors and pointed out that, although with deep shaft the oxygen transfer efficiency was excellent, the air had to be injected about one third of the way down the shaft: hence for a 60 m deep shaft the air pressure required was several times that needed for conventional diffused air systems. The overall efficiency may be measured in terms of kg BOD removed per kW hour; in the case of deep shaft this appeared to lie in the range 1.2–2.

Biological contactors appeared attractive, but unfortunately when this option had been priced for schemes by Thames Water Authority the capital cost had been rather high. When energy and capital costs were discounted in accordance with the Government guidelines the system was uneconomic.

As far as variants of the activated sludge processwere concerned, dramatic energy savings might not be possible, but advanced treatment might be achieved by extended aeration with a high quality effluent, with both nitrification and denitrification, using dissolved oxygen control. At the same time energy consumption could be reduced. Possibly further economy in both capital and running costs might be achieved if a separate return sludge pumping station could be eliminated. By decanting supernatant effluent, and retaining mixed liquor within the aeration tank, a capital cost saving in excess of 20% might be achieved, with some saving of energy.

Mr Ray asked the author if he would comment on the merits of including rotating contactors within an activated sludge system, both for uprating capacity and to save energy.

Written discussion

G. TAYLOR (Thames Water Authority) wrote that in discussing effluent standards Mr Haseldine had referred to the tendency to produce effluents of unnecessarily high quality. In the past, River Boards had often been glad to have such effluents to offset inferior effluents discharged elsewhere into the same stream. The water authorities were in a position to control the quality of effluent from each works to achieve a satisfactory stream, and 'fine tuning' on a day-by-day basis might become an accepted energy saving procedure. Such an approach, however, would call for greater flexibility in design, especially of activated sludge and effluent recirculation filter plants, to provide for diurnal loads, and cover the vagaries of shifting populations and variable industrial loads. Mr Haseldine's opinion on the energy saving potential of the introduction of a denitrification stage into an activated sludge plant would be appreciated.

Author's reply to discussion

Mr Haseldine in reply thanked all those who had contributed to the discussion. Mr Rofe had referred to the injection of polymers into sewers and rising mains; although it had been shown that this could enable more sewage to be carried in the existing system, thus saving capital expenditure on laying duplicate pipelines, it was doubtful that the injection of polymers would save energy overall in view of the amount of energy used in producing the polymers. The author agreed that there was considerable scope for energy saving by using microprocessors in controlling treatment processes but it was probably only worthwhile for large activated sludge plants. Mr Bayley had made a most useful contribution and had drawn attention to the very low energy consumption of even the most complicated sewage treatment process. The author agreed that if the cost of energy continued to increase in real terms, there would be a trend towards using the biological filtration process for new plants.

Mr Rundle had referred to the energy used in recirculation on biological filters. The author agreed that recirculation had little, if any, effect on final effluent standards and, therefore, should be kept to the mimimum necessary to prevent filter ponding. On the subject of the oxygen efficiency of activated sludge plants, the statement that 'as the loading increases so the oxygen required per unit mass of BOD removed reduces' seemed to be in accordance with the law of diminishing returns which affected every aspect of both water and sewage treatment. The author could not give an authoritative view on the ideal loading for an activated sludge plant; it was something that could well be investigated by using the Sewage Treatment Optimization Model (STOM) referred to by Mr Rofe. The author could not see any good reason for insulating the floors of digestion tanks. Water in fact was not a good conductor of heat and provided the groundwater was not flowing rapidly he did not consider that insulation would be justified.

Mr Martin's comments in amplification of his previously published paper and Mr Davies's review of current work at WRC were a valuable contribution to the subject and the author looked forward to seeing the outcome of this work published in due course.

The author agreed with Mr Pennington that the best way of dealing with variations in flow at large sewage pumping stations was to have variable speed drive units: however, some efficiency was lost in the drive unit itself which should be set against the improved pump performance.

Mr Ray had given some useful details on the deep shaft process and rotating biological contactors. Both processes were in their infancy and the author hoped that future developments, including combining the rotating contactor with the activated sludge process, would be successful.

Mr Taylor's written contribution had referred to the Water Authorities' duty to maintain the standard of purity of their rivers. The author was not suggesting that river quality should suffer, and he was only referring to blatant cases where the effluent quality was unnecessarily stringent and where a reduction in quality would have no significant effect on the receiving waters. In reply to Mr Taylor's final point, the author did not consider that the introduction of a denitrification stage would theoretically save energy. The denitrification stage must use a nominal amount of energy to maintain proper circulation and it could only work if the effluent was fully nitrified. Hence, if a works was operating at its maximum capacity to produce a nitrified effluent, the introduction of a denitrification stage meant building more tanks and using more energy. However, on some existing works, the introduction of a denitrification zone had resulted in energy saving, but this was only because the works were under-loaded and too much energy was being used in the first place.

4. SEWAGE - DEVELOPMENT OF BY-PRODUCTS

G.S. Clapham, BSc, MICE*

Consideration has been given to exploiting sewage as a resource. Substances contained in sewage include metals, fibre, protein, oils, fats, chemicals and water. An assessment has been prepared providing an indication of past practices and possible developments for the future in recovery and recycling on a national basis of the major constituents in sewage. Adopting such an approach will help reduce pollution of the environment and conserve the earth's natural resources.

INTRODUCTION

SEWAGE - not a word that usually stimulates much interest or further thought: more likely than not it would promote a rapid change of subject.

However, in the discharge of sewage we as a nation throw down the drain about £150m each year. It can be appreciated therefore what a valuable resource sewage really is. Sewage contains metals, fibre, protein, oils, fats, chemicals, vitamins, fuel and of course the carrier water: if these could be recovered and recycled what a benefit this would be to the national economy.

This is of course where the problem starts. "We have the technology - we can recover." It is the cost which is usually the main obstacle. Recovery is undertaken when it is an unavoidable part of the treatment process. For example sludge is produced in the treatment of sewage and biogas is produced in the treatment of sludge. Opportunities to recover substances from sewage which can be shown to be economically viable at present are very limited.

As raw materials become more and more expensive, particularly those which have to be imported, then increasing attention will have to be paid to resource recovery.

As real progress is made in by-product recovery this will also have the significant additional advantage of removing and overcoming pollution problems. The conservation of our ecology will be better protected. An example of this is the present toxic metal problem associated with the disposal of sewage sludge.

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In The Past

Production of sewage by-products is not new and to illustrate this the Bradford Corporation Gas and Improvement Act 1871 re the defaecation of sewage, Clause 46 states "The Corporation may upon such terms and conditions as may be fixed by agreement with the owners or occupiers of any lands contiguous to sewage works of the Corporation supply to such owners or occupiers respectively sewage for the fertilisation of such lands". In 1873 the first treatment works was completed and the process was to strain the sewage through peat in order to purify the effluent and to extract its manurial properties at one and the same time, afterwards drying the peat under cover and recovering the cost of the process by selling the product as a manure for agriculture. In 1909 bags of this manure were exported to France.

This is but one example of efforts of the past to try to maximise the benefits from the treatment of sewage: an objective we are still trying to achieve today.

In The Future

Improvements in the usage of present techniques and introduction of new technology will undoubtedly help make the recovery of more resources a viable proposition in the future.

There seems little doubt with increasing demand being placed on the world's finite resources that every opportunity will have to be taken to recover from waste and recycle whenever possible.

In order to appreciate the range of substances recoverable from sewage and their potential value, Table 1 has been produced. In considering Table 1 it should be noted that when a recovery method and usage are considered in respect of any one particular substance it can mean that other constituents are not then available for recovery. To examplify this, if sludge is not digested biogas is not available.

It is accepted that, in the foreseeable future, total resource recovery is not a feasible proposition if only because sewage is often only available at many diverse locations in minimum quantities. However selective resource recovery is becoming increasingly attractive with the advancement of technology and examples of this are given later in the paper.

A precis of the situation relating to history and progress made in respect of each recoverable substance has been included in the following text.

TABLE 1 - Estimated Quantities and Values of Substances contained in Sewage on a National Basis.

Substance	Discharge/annum		Value £/tonne	Total £/annum
Sewage	2740×10^6 m^3		-	-
Sludge	1.2×10^6	dry tonnes	-	-
	30×10^6	wet tonnes	-	-
Nitrogen (N)	63,000	tonnes	250	16×10^6
Protein	390,000	tonnes	200	78×10^6
Phosphorus (P)	20,000	tonnes	600	12×10^6
Potassium (K)	4,000	tonnes	150	1×10^6
Fat	180,000	tonnes	200	36×10^6
Oil	37,000	tonnes	120	4×10^6
Fibre	150,000	tonnes	-	-
Sugar	5,000	tonnes	-	-
Starch	11,000	tonnes	-	-
Vitamins				
B_{12}	0.3	tonnes	4,200,000	$1{,}3 \times 10^6$
Thiamin (B1)	1	tonne	21,000	0.02×10^6
Riboflavin	0.25	tonnes	-	-
Zinc	1200	tonnes	400	0.5×10^6
Cadmium	36	tonnes	3,000	0.1×10^6
Copper	480	tonnes	1,000	0.5×10^6
Nickel	150	tonnes	2,700	0.5×10^6
Chromium	360	tonnes	3,500	1.3×10^6
Iron	7000	tonnes	-	-
				£150m
Biogas				
Gas	570×10^6 m^3		6p/m^3	£34m/annum
Petrol	80×10^6	galls	£1.30/gall	£100 x 10^6/ annum
Water	2740×10^6 m^3		20p/m^3	£550 x 10^6/ annum

The Table has been produced on the basis of the make up of a typical co-settled sludge.

NUTRIENTS

Sewage contains nitrogen (N), phosphates (P), and Potassium (K) valued at about £29m annually. These nutrients together with other trace elements would provide a sound base for plant fertilization. Not being a complete fertilizer some further balancing is normally necessary. However it must be stated that liquid digested sludge with its readily available nitrogen is ideal for grassland.

The increasing cost of fertilizers make it essential that the proper development of these sewage nutrients is achieved: this is becoming increasingly essential as inorganic fertilizers are mainly oil based.

The concentrations of N.P.K. vary significantly: only a small amount of K is present.

Table 2 shows the typical N.P.K. concentrations and their potential value.

TABLE 2 - Average Percentage Nutrients present in Sewage and their Estimated Value.

Liquid Digested Sludge Typical presence on % Dry WT. Basis		Annual Value £m
5% Organic Nitrogen	(N)	16
5% Phosphorus	(P)	12
0.3% Potassium	(K)	1
		£29m

The main question is how best to make these nutrients available. There are the following options:-

(a) dispose of the sewage sludge direct to land

(b) by use of the hydroponics technique

(c) recover each nutrient

Sewage Sludge to Land

Sewage Sludge is an inevitable by-product of the sewage treatment process. It is usually about 98% - 99% by weight water. Organic and inorganic compounds are present. Nationally some 30 million wet tonnes have to be disposed of annually to land or to sea. Of all the by-products produced from sewage treatment, sludge presents the biggest single disposal problem. If all the available sludge nationally was disposed of on land in a liquid form at an average dosage rate then about 600,000 hectares would be required annually.

The cost to the nation in disposing of sludge is about £2 per head or about £100 million annually: this is over one third of the total cost for the treatment of sewage to deal with 0.5% of the volume. Jamieson (9)

It is likely that sooner or later with less land being available, tighter pollution control limits being imposed and the ever increasing demand for food will make it essential that proper sludge management is provided to ensure maximum utilisation of the nutrient value whilst keeping disposal costs to a minimum. The need for proper sludge management is also becoming more important in the U.S.A. Taff (1)

To ensure this is possible it will most likely be necessary to implement a more stringent trade effluent policy to regulate the potentially toxic substances to limits which will ensure proper future protection of the environment. It will also be necessary to be able to overcome the inherent resistance to its use because of possible risks to health, whether these be mainly psychological or not.

Without doubt sludge to land remains the best option for the foreseeable future.

It may be that to satisfy public opinion sludge will have to be digested first as this has become a form of sludge treatment generally accepted by the community at large before disposal to land.

The other immediate alternative is sub-soil injection. If this can become a nationally acceptable method a significant saving in capital expenditure is possible.

Hydroponics

This is a method of crop cultivation which is becoming more commercially popular. The application of nutrient film techniques (N.F.T.) is a very simple concept. A shallow stream of water containing all the dissolved nutrients required for growth is recirculated past the bare roots of the crop plants in a water tight trough. If sewage could be used as the nutrient carrier then only nutrient make up necessary would be needed above the level already contained in the sewage.

Research on the application of sewage to the hydroponics technique is already being undertaken. Experimental work is at present being carried out by Bath University on tomatoes, lettuce, mint and grass at the Keynsham Sewage Treatment Works of the Wessex Water Authority. Similar work is being undertaken at the Havant S.T. Works of the Southern Water Authority by the Portsmouth Polytechnic.

Nutrient Abstraction

As long as land disposal is available it is not likely that direct abstraction would be viable. However, should this be needed in the long term it could possibly be achieved through the application of biotechnology.

BIO-GAS

Anerobic Sludge Digestion was introduced in the early twentieth century primarily to combat increasing complaints by the public about the nauseating smells which arose in the disposal of crude sludge. A by-product from this process is bio-gas, often referred to as "Methane", with a calorific value of about 22000 KJ/m^3. A summary of data relating to bio-gas is given in Table 3. To provide digestion capacity is costly in both capital and operating costs. For the digestion process to operate satisfactorily the temperature of the sludge has to be kept at around 35^oC. To achieve this about half of the sludge gas is required for heat. However, it is possible that by improved insulation, improved operating techniques and the introduction of gas re-circulation that the volume of surplus methane could be significantly increased. Perhaps more use could be made of waste heat sources such as generating stations or incinerating plants to provide the heat necessary to sustain the digestion process and thereby release even more bio-gas for external use.

TABLE 3 - Summary of Data relating to Bio-gas

BIO-GAS	
Carbon dioxide	33.4%
Methane	64.9% + some H_2S
Hydrogen	1.7%
Possible volume produced nationally *	$570 \times 10^6 m^3$
Cal value	22000 KJ/m^3
Volume produced/head/day	0.03m^3
Petrol equivalent *	80 M galls
Value *	£100 M

* if all sludge were digested

Much effort has over the years been put into devising ways of using this surplus energy. Such schemes have included the introduction of dual fuel engines for generating electrical power, the provision of low grade heat for room heating and various projects to devise a method of providing a fuel for vehicle propulsion.

A striking example of the use of bio-gas, following liquidation, for the propulsion of vehicles was at the Mogden Sewage Treatment Works, West Mogden, during the Second World War. Parker (2). Vehicles were equipped to run on methane gas. The main problems in using bio-gas this way are in the high capital cost of the scrubbing and compressor equipment, the cost of the carrying and conversion equipment necessary on each engine and the corrosive impurities. Considering the present world energy situation, the potential 80 million gallons of petrol from sewage has been of sufficient attraction to warrant further development. Of course much more investment would be required in the provision of digestion centres, and improved operating techniques would be required to optimise bio-gas yield. It will not be practicable to digest all sludge produced nationally and therefore the actual benefit achieved would undoubtedly be somewhat below the maximum possible.

Recent examples of development in this field are the 'Totem' and 'Hamworthy' engines which generate electrical power direct from bio-gas without the need for scrubbing or compressing. At the time of writing the trials being carried out in the Wessex Water Authority are proving very satisfactory. The estimated pay back period based on the value of the energy produced is about two years: it can be seen that this makes the venture very attractive. Now that mini-digestion units are also being developed a power unit such as this would enable a small works to be independent as regards electrical power: reliability will however need to be proved.

Bio-gas can also be sold direct to industry and this is a practice adopted by water authorities. An example is the sale by the Wessex Water Authority of some 60m^3/day of bio-gas from the Poole ST Works to Hamworthy Engineering Limited which is sited adjacent to the works. Other similar outlets are being sought.

The most common method of using bio-gas in the past has been by way of dual fuel engines these have in the past been limited to the larger works, say those serving above 200,000 population. The engine derives its power from the methane in the bio-gas but the engines also need a nominal 10% of diesel fuel for ignition purposes: the engines can also operate on diesel fuel alone if needed. Two factors have tended to inhibit their development. Firstly the low cost energy available up to the 1973 oil crisis: this resulted in the cost per unit of power generated being close to or in excess of the cost charged for mains electricity. The second is the need for highly skilled supervisory staff. Increasing energy costs could bring dual fuel generating stations back into favour. Such stations could become more efficient in the use of the gas available. Improvements worth consideration are Alder (3):-

> Store excess gas during summer periods; better insulation of digestion tanks; increasing efficiency of digestion process by sludge thickening and improve control and monitoring of digestors and digestor loading to optimise gas production, introduction of grass to increase gas production.

PROTEIN

TABLE 4 - Typical concentrations of Protein in Raw and Secondary Sludges and their estimated value.

Source	Protein Concentrations
Raw sludge	17%
Secondary sludge	40%
Value	£78m/annum

Of the sewage sludge produced nationally about 390,000 tonnes of protein is discarded to waste. The concentrations and value are given in Table 4. Protein recovered in this way could be used in agriculture generally as an animal feed supplement or as a fertiliser: protein fertiliser products have been produced equivalent to dried blood.

The exploitation of sewage sludge as a protein source is not new and has already been the subject of extensive research and development. Indeed it has only recently been reported that Cardiff University has been successful in perfecting a chemical process to separate protein. They were quoted to say "It could be quite palatable to humans, we've tried it."

Similarly Wessex Water Authority are collaborating with a private consortium on research into protein recovery from sewage.

Commercial plants are already in production to extract protein at its source where it is concentrated, such as abattoirs, tanneries and dairies. Jones (11).

If sewage sludge protein can also be converted into fish or meat in this way on a commercial scale then this would be a short direct way of recycling protein, and could have a dramatic impact on the under developed countries of the world when considering the ever increasing demand for food.

The fundamental requirement is to ensure a reasonably pure and sterile end-product. Residual toxic metal concentrations would need to be kept within accepted limits and the protein would also have to be disease free.

To be confident that any protein can be put into the food chain and will not cause any disease or other adverse effects will require extensive controlled feeding trials over several generations. It is only in this way that market acceptability will be achieved and the inherent psychological resistance to any 'sewage' derived products overcome.

Protein extracted from activated sludge has already been fed direct to trout as a supplement to its normal feed. The fish survived well on all diets. The main difference detected was that the fish fed the highest sludge protein diet showed the highest weight gain. In addition, these fish showed a higher conversion of food into protein and a lower fat concentration. All of which indicates considerable promise, particularly when it is considered that fish caught in the South Atlantic is imported into this country as food for 'fish farms'!

Another venture was the feeding trials carried out on poultry by the TWA and a commercial operator. The tests comprised the introduction of dried sewage sludge into the diet of the poultry on varying percentages in place of the normal foodstuffs. In this case the trials did not prove the success hoped for, but of course it is only in carrying out such work that progress can be made. Further work is proceeding.

Protein extraction would provide water authorities with an alternative method of sludge treatment. Perhaps because of the lower concentration of protein in the primary sludge this could still be digested in the conventional way to provide the necessary energy requirements for the protein extraction process from the secondary sludge.

An alternative way of producing protein is by rearing course fish in final effluent lagoons. Sewage sludge is fed into the lagoons as the nutrient source, this generates the rapid development of natural flora and fauna. The fish, usually carp, then feed on this food source. The growth rates have proved to be exceptionally high. Experimental lagoons have been installed at the Avonmouth, Ringwood and Sturminster Newton S.T. Works of the Wessex Water Authority. Again, work has also been done on similar feeding trials both in this country and abroad. Noble (10).

METALS

TABLE 5 - Estimated type and weight of Metals discharged nationally and their total value.

Metal	Tonnes/annum	Value
Zinc	1200	
Cadmium	36	
Copper	480	
Nickel	150	
Chromium	360	
Iron + Trace	7000	
	9226	£2.9m

In general heavy metals are usually present at low concentrations in sewage. However, they do present a problem in the disposal of by-products produced from sewage as will have been seen from earlier sections: sewage sludge and protein are two such examples.

Metal contaminants found in sewage include zinc, cadmium, copper, nickel, chromium and iron which originate from a wide variety of sources.

As seen from Table 5, nearly 10,000 tonnes of metals come down the sewers most of which is iron. Their value excluding iron is about £3.0m. The cost of introducing electrolysis plants for metal removal at the sewage treatment works would be prohibitive at present. Similarly, it would at present be too costly to carry out metal precipitation by ion exchange.

Undoubtedly the most convenient point where metal removal can be carried out is at their source where they are most concentrated. In many instances this is already done and at a profit, but the practice needs extending.

If a by-product recovery and use is to be possible in the future then more stringent trade effluent control will be required to reduce the resultant problems to a minimum.

However, recently the innovative development of Biotechnology has been reported which gives ground for optimism in the recovery of metals. The present state of development of Biotechnology is said to be where the silicon chip was 25 years ago.

It will be dependent upon the genetic engineers' skill whether or not it will be possible to develop specific strains of micro-organisms to leach out particular elements. This approach shows the best promise for the future in recyclying the world's metallic resources.

FATS, GREASE AND OIL

TABLE 6 - Estimated weights of Fats, Oils and Grease discharged nationally and their value.

	Tonnes/annum	Value £
Fat/Grease	180,000	36m
Oil	37,000	4m
		£40m

Little is done to recover fats, grease and oil. They can be readily broken down in the normal digestion process. As long as these substances do not impede the flow of sewage or inhibit the treatment of sewage then they can be dealt with in the normal treatment processes. Simpson (7).

It is only when grease or oil is present in greater quantities that problems arise. Examples are in the heavy wool districts and at the holiday resorts where 'chips with' result in significant high fat discharges.

Grease and oil traps are put into sewerage systems as standard to limit the discharge but despite this the oil and fat content in sewage can still be high. As an example because of the high concentrations of grease in the sewage (up to 640 mg/l) discharged from the woollen district around Bradford, Yorkshire, treatment by conventional systems was virtually impossible. To counteract this, a grease recovery stage was built into the treatment works when it was constructed. The recovered grease was then processed and refined to produce a range of by-products. These included various grades of grease, soda soap, sheep marking fluids and paint bases. The recent decline in the woollen industry has however reduced the grease content in the sewage to the point where recovery has become unnecessary and the by-product operation uneconomic. This stage of the process has since been disbanded. It may, however, be of interest to note that in their 'hey-day' the recovery and sale of grease and associated by-products helped off-set the high cost of sewage treatment; the cost to general ratepayers on occasions being reduced by up to two thirds.

This does demonstrate how by-product recovery properly organised can help significantly to reduce the costs to the public.

WATER

The by-product with the largest volume is water. There is some 2700 million m^3 being discharged in rivers and seas nationally each day. This would have a value of about £500m per annum if it were recycled as potable water.

Already in many areas where conditions are right sewage effluent is treated to a standard sufficient to produce industrial grade water. An example of this is the production of industrial water at the Avonmouth S.T. Works of the Wessex Water Authority. This water is used in various manufacturing processes by adjacent industry. A similar example is at the Westbury S.T. Works

Most of the waste water discharged nationally could be made available for use either as an industrial supply or if need be as a potable supply. Research work has been carried out in the past resulting in techniques being developed to provide a reclaimed water supply. Eden et al (5).

Of course, many rivers and streams depend for their existence on the discharge of a treated sewage effluent. One such example is the River Thames. In this case use and reuse occur quite naturally.
It is said that the Thames' water is abstracted, used, treated and discharged 3 to 4 times before it reaches the sea: quite an economic arrangement in the use of water.

The growing population, coupled with high standard of hygiene, has led to a steady increase in the demand for clean water throughout the UK. This situation will increase the proportion of sewage effluents to rivers which in turn will require improved standards in the effluents discharged in order to protect the river systems: particularly if they are required for water supply. A vicious circle occurs.

The only real option available in the long term will be one of recycling water direct from sewage effluents to a potable standard.

Process techniques which could be considered for reclaiming high quality water from secondary sewage effluents are :-

Activated carbon

Chemical treatment

Ozone treatment

Ion exchange

Thermal process

Membrane processes - Electrodialysis

Reverse Osmosis

Of the processes available reverse osmosis seems to show the most potential. As an example Table 7 gives an indication of possible performance with this system. Bailey (4).

If final sewage effluent could be used for hydroponic application as a first stage treatment, followed by reverse osmosis as a second stage, this could form a realistic method for producing industrial or potable water.

TABLE 7 - Composition of Sewage-Works Effluent compared with that of Water obtained from it by Reverse Osmosis and with that of the original tap water.

	Filtered sewage effluent	Reverse osmosis product	Tap Water
Gross properties			
Total solids	660	58	390
SS	6	0	0
Colour (Hazen units)	22	0	0
Turbidity (ATU)	9.4	3.6	0
Conductivity (mhos/cm)	990	81	620
Inorganic constituents			
Ammonia (as N)	< 0.4	<0.4	0
Nitrate (as N)	31.4	6.0	5.0
Nitrite (as N)	0.03	0.02	0
Chloride	75.3	5.3	17.0
Sulphate	66.8	2.0	14.8
Total phosphorus	2.75	0.07	0.03
Total hardness (as $CaCO_3$)	262	13	280
Organic constituents			
PV	4	0.6	< 0.3
COD	52	∼1	∼3
Organic carbon	8.5	<0.5	<0.5
Anionic detergent (as Manoxol OT)	0.9	∼0	0

Units mg/l except where otherwise stated

In the development of water resources strategy by Water Authorities the option which should be included is the possibility of providing a source of water from the recycled treatment of sewage effluent.

There is value in this resource being exploited to the full when it is considered it is worth over £500m per annum

WASTE RECYCLING

With ever increasing industrialisation, the throw away society has more and more waste to dispose of and waste disposal problems do not only relate to sewage. There is an equal problem associated with the disposal of domestic refuse with the need to transport it over increasing distances to fewer and fewer tips. If these two problems could be dealt with together, the community at large could benefit enormously.

Composting of sewage sludge and domestic refuse has already been introduced at a number of centres throughout the country. There does seem a reluctance between Authorities concerned to introduce further similar joint ventures. Stead (6).

There is however a process being developed which involves the processing of sewage sludge and domestic waste in such a way that would recycle marketable products to industry. There would be a recovery of ferrous metals, plastics and glass. In addition it is envisaged there would be produced fuel, fibre and organic products plus land fill material of marketable quality. This recycling project seems to offer significant prospects for the future and information on development will be awaited with interest.

There seems little doubt that an approach to waste disposal combining sewage and domestic refuse will be needed in the future.

ANCILLARY SUBSTANCES

In respect of the other substances such as sugar, starch and vitamins, further advancement will be needed to recover these direct: it may be another application for biotechnology as it develops in the future.

Alternatively ways may be possible through the manipulation of other recovery techniques to make them available indirectly to industry. An example would be for protein to include the vitamins in the recovery process.

These substances have a potential annual value of over £1.5m.

CONCLUSIONS

From the foregoing it can be appreciated that sewage rather than being that repugnant nauseating substance not to be talked about is a wonderful resource waiting to be exploited. The purpose of this paper has been to highlight this.

The by-products available from sewage are extensive and as will be appreciated the short discussions presented on each topic only touch the surface on these subjects. Indeed, each topic could well form the basis of a paper in its own right.

Many of the by-products are both inter-dependent and inter-related. The particular solution to by-product recovery and re-use may be a mixture of the matters discussed. For example, biogas could be used for greenhouse heating with plant nutrients being provided through hydroponics using sewage. The range of such options is enormous.

The principal stumbling block in many instances to exploiting resources in this way is cost. Often such schemes are not cost effective to the water authorities.But to the nation they make economic sense. Perhaps the Government could look more sympathetically in financially supporting such projects.

It is also recognised that to make a point it has been necessary to delve into fantasy on occasions and that it is perhaps a little unrealistic to assume that all constituents of sewage will be recovered and recycled. It is accepted that there are limitations and undoubtedly there are many practical problems. This should not however detract from pursuing a policy of recovery and recycling and thereby reduce future potential pollution problems, protect the world's resources and last, but not least, reduce the basic cost of sewage treatment.

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DISCUSSION

Verbal discussion

E.C. REED, OBE, DFC (Thames Water Authority) said that over the years pundits had placed before various committees facts and figures concerning the possible uses of sewage sludge. In this paper Table 1 gave, on a national basis, estimated quantities and values of substances contained in sewage. Perhaps more relevant when considering such statistics, was the fact that there were some 4400 sewage treatment works and numerous sea outfalls situated in England and Wales, of which only 30 had a flow greater than 50 Ml/d, a further 170 having a flow between 10 and 50 Ml/d. There must be a minimum size of works where recovery of by-products was a viable proposition. Below a certain size of sewage works, recovery might not be economic and the cost of extraction processes would out-weigh the benefits involved. Could Mr Clapham say what size a plant would have to be for extraction of the substances which he values to show energy benefits? In Delhi a sewage works supplied methane gas to a housing estate for cooking. This is an interesting use not mentioned in the paper.

At present, sewage often contained numbers of undesirable substances and he agreed with the speaker that, in the longer term, there was a need for a trade effluent policy that would limit much more drastically those substances which, when discharged into the sewerage system, caused concern particularly when sewage sludge was to be disposed of by spreading on land or discharging at sea.

There was considerable interest in the extraction of protein from protein and Wessex WA seemed to be proceeding apace. Here again he would sound a word of caution that any process must be viable both in cost and energy terms. In Thames WA research had been along the following lines:

(i) direct re-use as an animal feed
(ii) a fundamental approach to the chemical potential
(iii) chicken feed
(iv) fish food supplement.

For direct re-use as an animal feed, there was a need to ensure that the problems associated with toxic metals were illiminated. So far there appeared to be no economic method of removing metals from sludge and therefore, this use was limited. The fundamental approach had met with some technical success in respect to grease extraction and protein isolation. Some problems with pesticides and metal carry-over had been found and there had been some success in isolating them. It was worthwhile noting that individually the recovery processes appeared to be on the borderline between being economic and otherwise. Thames's involvement over the last 3½ years had met with success but had shown that, to be viable, only the flows at the largest works could be used. Another point worth registering was that there was considerable technological know-how in the chemical and food processing industries which should be harnessed if at all possible. An easy way for water authorities to join the work with industry would be of benefit to all.

Thames WA had carried out some feeding trials using raw sludge mixed with standard foodstuffs and made into a range of chemically balanced diets. The trials tended to show that the feeding value of the diets was less than expected from their chemical compositions. Feeding pelletized activated sludge to fish had been much publicized in the UK. Thames WA was researching into the growth of trout on a diet containing activated sludge to see whether higher growth rates that with conventional feeds could be obtained.

Although the re-use of sewage by re-cycling to the clean water side could be carried out using well known technology, there was nevertheless the need to consider the viability of the process with regard to expenditure, return on capital, and energy consumption. In a drought year such schemes came to the fore in this country. However, by and large in the United Kingdom and Europe there was sufficient clean water to meet present needs. In some areas re-use of effluent could well be viable, if not as potable water, as a second or third class supply for industrial or agricultural purposes. During the 1976 drought Thames WA supplied in excess of 2 mg of treated effluent for football pitches, racecourses, and a wellknown London cricket pitch.

Sewage sludge undoubtedly had a potential value, no one had yet made big money from the extracting of substances from the sludge. Present separation technology in other industries concerned with chemicals and foodstuffs was very advanced. Could they inject into the water industry some of these technologies? When they did, they must ensure that what was being done was economic, a benefit to the industry and, in the context of this symposium, ensured that the energy balance was correct.

J.S.M. WILLIS (Consultant) said that the author had given an entertaining and very informative review of the possible uses of sewage by-products, but it was important not to allow the wide range of these possibilities to obscure the priorities and economics of the subject. Mr Clapham had spoken of throwing valuable assets down the drain, but the figures quoted in the paper implied that their recovery was not only practicable, but free.

The three top priorities surely must be the capture and use of energy, fertility and water. The reclamation of energy from biogas was well established, but present circumstances required a drastic rethink as to the cases when this should be done, as well as powerful efforts to improve the technology and efficiency of the process. The author had mentioned the development of spark-ignition engines to run on biogas, of improved sludge thickening and digestor management, and of digestor insulation; there appeared to be plenty of scope for improvement in all these fields. Sludge digestion was likely to be adopted much more widely, even at quite small works.

As for fertility, a glance at the paper showed the great waste of plant nutrients whenever sludge was not returned to the land; and this should be seen against the utter dependence of British agriculture upon artificial fertilizers (whose production is a significant user of energy). The present position may be distorted by the pattern of agricultural subsidies, but no-one could be happy about the loss of fertility represented by sludge dumps, sea disposal, and incineration. Seen thus, the elimination of toxic metals from sludge may, to the nation, be worth much more effort and money than was being spent on it at present. Perhaps the problems of fully utilizing the fertilizer value of sludge would require Government involvement, but the water industry could point the way, and make a start by insisting that sludge disposal to land was a resource conservation, and not just a convenient way of getting rid of the stuff.

Then there was the largest by-product; water (as effluent). The speaker did not agree with the author's view that 'the only real option... will be one of reclaiming high-quality water from....effluents'; if only because the techniques he listed for doing this all seemed to be big energy users. But what about the use of effluent for plant growth? It was well known that there was an unrealized potential for crop irrigation in this country, and effluent was available (without having to provide expensive storage) throughout the growing season, it had its own fertility value (usually just cursed for causing eutrophication), and its removal from the river systems would take place during the summer when the quantity of diluent water might be at a minimum (so reducing the pollutant load).

Concentration on these three priorities was likely to be much more valuable than attempting to recover proteins for feedstuffs. In any case the protein in sludge might be quite as useful as fertilizer, as indicated by the author when he compared its manurial value to that of dried blood.

DR M.J.D. WHITE (Water Research Centre) complimented Mr Clapham on his entertaining presentation of a very wide range of possible ways of exploiting sewage and sludge. He agreed wholeheartedly with Mr Clapham, and the previous speaker, that the most cost-effective way of utilizing the 'resource' in sludge was digestion, to produce biogas, and conversion of the digested sludge to edible protein by spreading it on grass or arable land. In view of the presence of potentially toxic elements, and pathogens in sludge, he thought that more direct conversion of sludge to animal protein was unnecessarily complicated. He agreed that thickening was more important before digestion and that there would probably be a lot of small digestor installations built. He was most interested to hear of the experience with small spark-ignition engines and asked whether there was any information on the difficulty and cost of maintenance, whether heat could be recovered, whether small works could really be independent of the electricity grid, and whether Wessex WA were considering running vehicles on biogas.

Dr White was interested in the experiments on hydroponics at Keynsham, and requested further details. He asked whether the substrate for plant growth was final effluent, as he assumed that sewage itself would have too high an oxygen uptake rate. Clearly there was a benefit to the horticulturist in having a readily available source of nutrients, and this would probably take a small proportion of sewage works output. Dr White asked how big a hydroponic installation would have to be to take the full flow from the works. Similarly, in considering adding sludge to a lagoon to grow fish, how big would the lagoon have to be to take all the sludge from a works?

Finally, although Dr White accepted that they should not close their minds to the possibility of making more use of sewage and sludge, he felt some of the suggestions made by Mr Clapham were misleading. For example, it would not be possible to realize the value of both fertilizer nitrogen and protein, not the whole amount for scarce materials such as vitamins because if significant quantities were to be produced, the market value would fail. He hoped that Mr Clapham had his tongue in his cheek when he suggested that there was £600m of water in sewage. It might equally be suggested that energy could be won by extracting the hydrogen from the water!

Written discussion

G. TAYLOR (Thames Water Authority) wrote that the reference to trade effluents was timely, but the proper place for the recovery of valuable by-products was at the trader's premises. Mr Clapham had mentioned the grease recovery as carried out at Bradford, a process forced upon the city in years past as a result of complex situations, and often quoted as an example of municipal enterprise. The sad facts remained, however, that there were many lean years between the wars when the grease was a financial burden rather than a source of profit, and that the value of the recovered grease was but a fraction of its worth if it had been recovered at source. The process of grease recovery at Bradford was substantially the same as that adopted at traders' premises where the liquors were already hot from the scouring stages. To allow them to cool after entry to the sewers and then to process together with added sewage solids represented an energy waste.

Another example of energy wastage arising from the presence of trade effluents had occurred recently at one of the London works. A trader discharged a solvent which could, under conditions of reduced aeration in the activated sludge plant, give rise to a most unpleasant odour which had been observed at a distance of several miles. As long as this solvent was present, energy might be wasted in simply achieving an unnecessarily high effluent quality.

These two cases suggested that there might be many other fields where energy saving could be built into trade effluent reception policies. Other problems of trade effluents such as impact upon 'treatability' of sewage, digestibility of sludge, and limitation of the value or rate of application of sludge as a manure were well known.

Author's reply to the discussion

Mr Clapham, in reply to Mr Reed, said that he recognized that there were many small works and accepted that there would be many practical difficulties in the by-product recovery on such a small scale. The minimum size of works where by-product recovery could be achieved economically, depended upon the particular by-product concerned. For example, on protein recovery it would appear that a works serving a population of about 30000 would be the minimum to support such a project on present knowledge. However, as techniques were improved it could be substantially less than this in the future. Indeed, not many years ago, the production and use of biogas for generating electricity could only be done economically on works serving populations of 100000 or more. But now, with the introduction of such generating units as the 'Totem' engine with its extremely efficient heat recovery, generation could be carried out on works serving populations of 3000 or less. This had been made possible by the development of the mini digestion units which were now on the market. These gave the option of introducing digestion of sludge on works, at the very low cost of about £6 per head.

For fish farming of bream or roach the minimum practical size would be a works serving a population of about 5000. The same would also apply to the introduction of hydroponics: the operation could relate to both a small market garden venture or to a larger horticultural unit. Another incentive to a development of this kind would be to provide methane gas, if available, for heating purposes which would help make the operation very attractive.

He was interested in the Delhi project quoted by Mr Reed, and agreed that the use of methane gas in this way was attractive in the right circumstances. However, he was of the opinion that it would need to be a totally independent venture as in the UK the stringent requirements of the Gas Board would rule out such a joint project on economic grounds.

He agreed that progress on such projects as protein recovery from sludge needed to be cautious: this was the method of approach being adopted in Wessex. He pointed out, however, that in addition to the use of protein as an animal foodstuff, its use as a fertilizer was also being studied. Toxic metals were a problem which they had to be extremely aware of, and care would be needed to ensure, beyond doubt, that toxic metal build-up did not occur in animals or fish feeding on the protein diet. If, however, metal recovery could be achieved economically direct from the sewage or wastes discharged then protein recovery would rapidly become a more serious and realistic option.

The suggestion had been made by Mr Reed that re-use of sewage by recycling clean water was an option for the long term. Mr Clapham agreed with this, and accepted that at present there were ample clean water sources available but perhaps as the cheaper sources were harnessed, recycling of sewage effluent could be an alternative option to the development of cleaner sources. However, further use of sewage effluent as a second grade water was both desirable and practicable for industry and agriculture.

Whilst agreeing with Mr Reed about the advance technology which had been developed in the foodstuff industry, Mr Clapham considered that this technology was, in fact, now being introduced into sewage treatment processes and by-product recovery and that this would continue. But, as he pointed out in the paper, it was 'cost' which would dictate in the final analysis.

In respect of many of the comments made by Mr Willis, Mr Clapham was in wholehearted agreement. He had said in his paper that many recovery processes were available and practicable but again, cost was the controlling factor and was often prohibitive: scarcity was often the leveller. Sludge was produced at all treatment works and had to be disposed of in the most effective way. However, the developments occurring on this front should benefit the water industry, particularly in respect of soil injection which could overcome inherent objections to disposal of sewage sludge, but this would require acceptance at national level for incorporation into the guidelines.

There could be no disagreement with Mr Willis's suggestion that to recover high quality water from sewage effluents would be expensive, but in the future, as science progressed, energy might be cheap and plentiful. It would be necessary to harness only a miniscule portion of the sun's constant massive energy emission for this to happen. What was limited was the availability of potable water. This topic was also referred to by Dr White.

He did not agree with Mr Willis's suggestion that concentration on protein recovery was perhaps misplaced. The extent of this country's dependence on imported protein ought to more than justify the attention presently focused on this topic. This was happening on all fronts and recovery was being sought through worms, algae, fish, and sewage.

Regarding queries raised by Dr White on the use of the 'Totem' engine, experience to date had shown that the unit was almost maintenance-free but it was too early to give any meaningful, conclusive information or reliable cost data. Mr Clapham also thought that use of biogas as a vehicular fuel was a viable proposition despite problems of high cost in the scrubbing and compression of the gas. Another point raised by Dr White related to the hydroponic trials at Keynsham. Mr Clapham confirmed that the substrate was final effluent and not raw sewage: a basic objective of the study was to determine the most suitable types of plants or grasses which would grow in final effluent. It was difficult to be precise about the size of hydroponic unit needed to serve Keynsham but a good guideline was that 1000 units of nitrogen would require about one hectare. As Dr White had pointed out, it might be difficult or impossible to realise all the substances referred to in the paper. Indeed, fertilizer nitrogen and protein was one example, but as no allowance was made for the nutrient value in the final sewage effluent, perhaps it would be permissible to allow this degree of 'artistic licence' and include this in the table.

Mr Clapham agreed with Mr Taylor that the most appropriate place for recovery of many by-products was at the traders' premises. However, whether or not this was done more often than not came back to cost and can result in a waste of energy. In respect of the grease recovery carried out at Bradford, it was agreed that this recovery process was needed to enable the sewage to be treated and that the disposal of the grease did depend upon the market forces at the time. The examples where energy saving systems might be introduced were practical options, but as long as it was cheaper for the trader to discharge his waste down the sewer this state of affairs would persist.

5. ENERGY MANAGEMENT - THE THAMES EXPERIENCE

*G.A. Thomas C.Eng., F.I.E.E; F.I.Gas E; M.I.T.E (Member);
+G.D. Wright; I.P.F.A.; M.B.I.M.

> "The development of an energy-efficient society cannot be decided in an economic planning office. It demands a high degree of individual initiative and responsibility" (1)

INTRODUCTION AND OVERVIEW

Introduction

At a meeting of the Management Board of Thames Water Authority in 1974 it was decided that the Director of Operations and the Director of Finance should form a team to examine power tariffs. In the event the Director of Operations nominated George Thomas, the Mechanical and Electrical Engineer of Metropolitan Water Division and the Director of Finance nominated Douglas Wright, the Headquarters Audit Manager.

The project started therefore as a tariffs exercise and at the first meeting we agreed on the basis of the following figures that priority should be given to the examination of electricity tariffs (electricity accounted for nearly 70% of Energy Revenue Expenditure).

TABLE 1 - 1978/79 Energy Expenditure

	£'000
Electricity	11,309
Oil	3,061
Gas	58
Coal	1,627
	16,055

Note: In the interests of consistency the figures quoted in this paper are for the year 1978/9.

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* Mechanical and Electrical Engineer; Metropolitan Water Division
\+ Principal Loans Officer, Thames Water

A decision had then to be made on the organisation and management of the project in an Authority covering 5,000 square miles in which there were nine Divisions each with its own responsibilities. Fig. 1.

It is worthwhile reflecting upon what we were attempting to achieve in those early days when energy conservation was not upon everyone's lips and when the full implications of what was then referred to as "the oil crisis of 1973" had not been realised: (indeed there are still many high energy users throughout the country who after 7 years of cajoling by the Department of Energy and the Department of Industry have not taken energy management seriously). Since the oil crisis of 1973 when as a result of the Yom Kippur War the world price of crude oil quadrupled there has of course been the Iranian revolution of 1978/79 when as a result of a severe cut back in Iranian oil production the world price of crude oil doubled.

However in the Autumn of 1974 we were formed to establish whether Thames was buying its energy at the right price. Conservation, alternative sources of energy, alterations to plant etc., were not within our brief. It was if you like a Value for Money exercise.

The Management Board as has been said took the view that this was a responsibility which required a close collaboration between accountant and the engineer and from the outset it was made clear that operational necessity took priority over financial gain. Nevertheless even with this constraint there was, with goodwill, ample scope for tailoring operational cycles to suit the most advantageous tariff.

As the story unfolds it will be seen that other disciplines were brought in to play their part in this multi-disciplinary approach to the problem.

The Problem

Thames Water has a two tier management structure for carrying out the policies laid down by its Chairman and 61 members. There is the regional tier which has a planning, co-ordinating and monitoring role while the divisional tier carries out the day to day operations of the Authority. Fig. 2.

That is the situation in very broad terms but as in most organisations there is a fair degree of overlap and the line between policy making and execution of that policy is not quite so clear. What is abundantly clear in Thames is that Divisions have been given a considerable amount of autonomy and are expected to manage their affairs subject to very few constraints being put upon them by Region.

It was in this context that we approached the problem of our responsibility for ensuring that all Divisions were obtaining Value for Money in their purchase of energy.

Not only did we have to tackle autonomous Divisions and these over an area of 5000 square miles but the Divisions themselves differed widely. There were the two very large Metropolitan Divisions. The Metropolitan Water division (which was in effect the former Metropolitan Water Board) had a centralised structure and was continuing to monitor its electricity consumption as it had done prior to Water Reorganisation. Then there was the Metropolitan Public Health Division which formerly operated as the Public Health Engineering branch of the Greater London Council. It had very large works each with its own administrative organisation which had a duty to monitor power costs. Then there were the Divisions outside London, whose energy consumption though sizeable was overshadowed by the large London Divisions who accounted for 65% of the Region's expenditure on energy. Fig. 3.

The Alternative Approaches

Faced with the situation which has been outlined it was clear that our responsibility could not be properly discharged as Directors' nominees alone in addition to normal duties. We therefore considered several options but the following three options were the most significant.

The first option was to pull all the existing and future Divisional information in to the centre, i.e. past statistical information and either pay all energy bills centrally or obtain copies of all bills paid by divisions. The next step would be to run consumption and cost figures through the computer to produce statistics which would highlight those installations on a disadvantageous tariff by virtue of their high unit costs. A very simple approach and one adopted by some high energy users in the private sector. However, we were not a manufacturing industry. We were not dealing with a product which did not vary. We were not, if you like, manufacturing biscuits. As an industry we were subject to the vagaries of the weather, of flood, of drought, and of industrial pollution. This may sound like a case for inaction but it was in fact a careful thinking through of the practical implications before embarking upon a major exercise. For the buck does not stop at the computer. Someone has to ask the question "WHY" and the answer can only come from the Division and in the end from the operative who throws the switch. We concluded that our chances of success would be in inverse proportion to the distance between the person who asked the question and the person who answered it. And here when referring to distance much more than physical distance is implied but this will be dealt with later. The second option was to bring in an expert from outside the organisation. Someone who was a specialist in negotiating tariffs. Even in 1974 there were several such private firms in the field. We met with a representative from one of the better known of these specialist firms and discussed fully what service could be provided to Thames and heard of what they had achieved elsewhere. It appeared an easy option, bring in a specialist and the problem facing management will be solved. We then thought it through and concluded that yes our responsibility could be discharged in this way but in this instance the person asking the question 'WHY?' would not only be outside the authority but would have no understanding of the water industry. An accountant is well aware of just how much uninformed questioning an engineer, and indeed any professional can stand and weighing the benefits arising with this factor and any steps we might have taken to alleviate the friction, we decided that this was not the right solution to the problem.

The third option was to ask each Division Manager to nominate a member of staff to work on the project with the Directors' nominees. The nominees would then chair a working party formed in this way. The working party's objectives would be to decide on policy and to co-ordinate and monitor the work. At a Divisional level the Divisional nominee would be responsible for implementation of the decisions of the working party. This was the course upon which we then embarked.

Activity

At the first meeting of the working party it soon became clear that new systems would have to be set up to collect the information in order to determine whether installations were on a most advantageous tariff. Furthermore it would take 15 months for the first year's figures to be compiled and analysed. Attention was therefore directed to the purchase of liquid fuel, coal and gas in the intervening period.

In addition to keeping the directors briefed on developments and particular aspects a formal report was presented to the Management Board. This set out what had been achieved in the year and put forward proposals for the coming year. In one such report and taking account of the lead given by the Department of Energy a proposal to broaden the brief of the working party to energy conservation in its widest sense was put forward and accepted.

ENERGY WITHIN THE MANAGEMENT STRUCTURE

Divisional Nominees

It is not easy in a relatively short paper to span the activity of six years' and deal adequately with changes in the terms of reference of the working party and to some extent in its composition. Briefly, the Joint Chairmen were the Directors' nominees, one an engineer, one an accountant. The nine Divisional nominees were all engineers some mechanical others electrical, whose standing within their Divisions varied widely. Some were members of their Divisional management team others were called as advisors from time to time. There were also wide motivational and personality differences. It is also important to note that energy was a responsibility made additional to the other duties they had within their Division and as such could easily be considered a low priority.

The Nominee in the Divisions outside London

How then did the Divisional nominee operate within his Division on return from the bi-monthly meeting of the Regional Energy Working Party? Those on the Divisional management team reported to that team but energy was only one of the many problems facing such teams and had to take its place with the problems of manpower, finance, transport, and consumers.

Thus with the best of intentions and self motivated, the Divisional nominee did not have an easy task. The Divisional nominee less well endowed than this and for example confronting an unsympathetic Group Manager was in a much more difficult position.

The Nominee in London

In the Metropolitan Divisions the situation was quite different. In the first place the Divisional Managers of these Divisions were acutely aware of their high energy costs and each had formed an Energy Group. It was to this Group that the Divisional nominee on the working party reported and worked through. So with the active interest of Divisional Management and the high standing of the members of the group which included finance representation the Metropolitan position was sound.

EVOLUTION OF ENERGY MANAGEMENT

The Need for Change

Energy Management in Thames evolved, as do all living things which are intent on survival, to take account of changes in circumstances, and in order to overcome difficulties which were not at first apparent.

With the increasing cost of energy and the knowledge that finite resources of fossil fuel were being depleted the terms of reference of the Working Party were widened and management gave energy a higher priority. The influence of the Department of Energy on management's approach will be dealt with later.

The other factor was the difficulties which Divisional nominees were encountering in their attempts to implement working party policies without a separate identity and terms of reference. In this regard it was decided to re-recommend that each Division be directed to designate a member of staff as Energy Manager with specific duties and authority to carry out those duties.

The Role of the Energy Manager

A directive was issued to all Divisions calling for the designation of a member of staff as Energy Manager and placing upon him the following responsibilities which are those recommended by the Department of Energy. viz. The Energy Manager should be a person of sufficient standing with:

1. the direct and specific responsibility for the wise and careful use of energy throughout the Division;
2. the role of co-ordinating the work of each production function of plant operation, including office management and transport arrangements;
3. the responsibility to stimulate possible energy saving investment.

The Role of the Working Party

As outlined the Working Party was a planning, co-ordinating and monitoring body but it was also a forum for the lively exchange of ideas and experiences. Ideas came not only from within but contacts were made with:-

The Department of Energy
The Department of Industry
The Greater London Council
The Energy Technology Support Unit
British Gas Corporation
The Building Research Station
North West Water Authority
Southern Water Authority
The six Electricity Boards which supply Thames area.

In addition speakers from the Department of Energy and the Shell Oil Company as well as staff from within Thames addressed the Working Party.

Monitoring Performance was at two stages. The first was the annual gathering together of data on energy usage for every installation throughout the Region and the analysis of these data. This data gathering was a joint exercise involving Divisional finance and operations staff but the analysis and investigation of variances was undertaken by the Energy Manager.

In the idéal situation data was being passed to the Energy Manager on a regular basis throughout the year and corrective action taken at that stage. Savings accrued from identification of wasteful pumping or of defective mains or pumps. Where action took place in this manner the end of year analysis and enquiry was of academic interest only. This was however the exception and at the other extreme there was the unacceptable scurry through 12 months bills at the end of the year for 'Region's Central Statistics'. This is of course mismanagement and it was here that most of our problems lay with countless references back to events which had taken place many months previously. This introduces the second stage and that is the review of the Divisional information at Region and the translation of that information into the Regional Statistics.

Both the annual review and the exchanges at Working Party Meetings provided the basis for the planning of future activities. These plans were put to the Directors for approval each year at the time of the annual report on energy.

PUBLICITY AIDS

Department of Energy

The Department of Energy using the regional organisation of the Department of Industry provides a very full range of publicity aids.

The 'Save It' campaign material is in the form of posters, films, broadsheets, and the monthly publication 'Energy Manager'.

In addition there is an instant telephonic advisory service and the provision of technical staff to address industrial and commercial users on energy management.

The Department is making every effort to keep the 'Save It' campaign topical with the introduction of new material and posters.

Thames Water - House Journal

The Thames campaign has enjoyed the full support of 'Thames Water News'. This publication has brought events, campaigns and a regular feature on energy to the attention of its readers. Of particular merit was the colouring and designing energy poster competition it organised for the children of employees.

Other Industries and Organisations

The International Energy Conference in Birmingham in October 1979 was extremely effective in encouraging the exchange of ideas between the very varied participating bodies from both home and overseas.

Thames has adopted many of the ideas put forward at the conference and has continued to make further contacts with both public and private sector industries in the field.

Enlisting Public Support

It is proposed to include a leaflet on 'saving water to save energy' with the water rate bill to be sent to our 12 million consumers. Unfortunately unlike gas and electricity the domestic consumer will not obtain a direct cash saving from any personal action taken to save water.

Effectiveness

Publicity aids serve to bring to peoples' attention the main reasons for action and results of such action. The art is, in having taken the broad approach, to tailor the aids to the action required of particular individuals, e.g. design staff, plant operatives, office staff. If this is done then they can be very effective indeed.

It has been found that with posters there is a need for, as is exemplified in commercial advertising, a regular change of poster. If this is not done a poster becomes 'part of scenery' and loses its impact.

Other Possibilities

Other possibilities like launching a 'Save Water - Save Energy' campaign using Radio/T.V./Local Buses have been considered but this would require a decision at a national level for an industry wide campaign.

MOTIVATION

The Need to Motivate

Energy management like any other management activity requires motivation if the objectives are to be achieved. Furthermore, to be pragmatic, it must be borne in mind that there are in all organisations personnel who have a vested self interest in preserving the status quo or discovering a multitude of reasons why the rules should not apply to them. Any person who has attempted to contain offices at 66F (19°C) will know the host of forces that can be brought to bear to prevent such a seemingly Draconian minimum being enforced, including ever present industrial relations problems. Little consolation to the Energy Manager that he has both national campaigns and a host of automatic systems to draw upon in these circumstances!

Again it is vital that motivation is seen to be a continuing exercise and that any programme must look not only at the continuity of the exercise but be tailored to take account of the persons at whom it is aimed at any point in time.

Before embarking upon such a programme it is worthwhile taking account of the experience within ones own Authority or organisation together with that of others in both the private and public sectors who have been active in this field.

The Thames Approach

In Thames it was decided to start the motivation campaign at the top as there appeared little point in attempting to motivate from the middle and work towards the ends.

In order to obtain the enthusiastic support of top management a one day Symposium was organised at which Department of Energy technical experts put the case for energy conservation to the Authority's Directors, Divisional Managers and senior staff and related the case to the specific operational requirements of Thames.

The material for the Symposium was taken from actual Thames installations and the authors visited typical works with a Principal Scientific Officer from the Department and this officer was then able to present clear cases to support his remarks. For managers to have their own work presented as a possible source of energy loss (and hence ground for conservation) is a forceful exercise.

Having started at the top any 'Save It' campaign must then get its message to those personnel who are in a position to act in the operational sense. These personnel must then have illustrated to them the consequences of not taking action through a loss of benefit both to themselves and to the organisation. In the case of Thames the major ground for communication was the workforce responsible for pumping and for treatment works of both clean and dirty water. Other parts of the paper will indicate that this is where the energy usage is greatest and consequently the areas for achieving energy savings at a maximum.

The Targets

The major national motivation campaign has been that of the Department of Energy with its "Save it" which, when it was launched in 1975, made it clear that at least 10% energy saving could be achieved by good housekeeping alone.

As with any such campaign the setting of a target can be relatively simple. It is the quantification of the results which is difficult and particularly so where there are changes in demand, in equipment and in process methods and the entire operation is affected by climatic conditions. Whether the campaign has yielded the detailed saving at every level can never be measured but certainly the main slogan is instantly recognised and can be seen to have taken up in many other quarters. No doubt this work will continue but the foundation signs and slogans will be known for years to come.

Motivational Methods

Consideration of the problem at Thames leads to four methods of motivation.

1. "teach in" or similar, within each Division's normal framework.
2. encouraging use of the Suggestion and Award Schemes.
3. use of both "in-house" and externally produced publicity.
4. use of publicity to motivate children of employees who in turn are good motivators of their parents.

The method of using the internal Divisional structure has of course variations in that each Energy Manager implements his energy work taking into account the other demands upon management. Within the two major Divisions there are sub-groups that sit to consider energy matters and here practical cases are considered. The Suggestion Scheme method is worthwhile if the opportunity is taken to 'work in' a special award related to energy.

Results

Some examples of the work that have proved useful to both management and managed alike are:-

1. the necessity to balance aeration tanks to the minimum required in order to maintain effluent quality at the accepted level. Here it was pointed out that a reduction $1000m^3$ of air would give a consequent saving of 15 kWhrs.

2. the necessity to study both the terms of energy procurements (tariff) and the use of machinery in that to use two units to pump 100 ml to a head of 54.9m for a day saved 10870 kWhrs in electrical input, but nothing in monetary terms. The reason of course being that the introduction of a second unit imposed peak demand charges.

(Here it should be noted that Department of Energy guidance is that any energy conservation scheme should meet conventional accounting "pay-back" criteria. It must be clearly defined in an exercise relating to energy what the ground rules are - saving money or saving energy. Certainly at the moment many novel forms of production are ruled out on financial grounds.)

Recently two examples were considered. The first the filling of a 38,010 M litre reservoir 1 cm above the required level. Using a 1.92 M Watt pump this meant the unnecessary use of 1,620 kWhrs of energy. A second was the comparable head (and hence energy) loss that would be occasioned by use of an orifice plate to meter a flow of 4000m^3/hr for 4000 hrs per year against using a venturi for the same purpose which with its lesser restriction meant a saving of 320,000 kWhr/annum (2). Such every-day examples and details can be carried by the motivator and put before personnel at each occasion an opportunity arises. Such facts are meaningful to plant personnel already made aware of the overall situation by publicity.

Future

In the future development it is proposed to institute an award scheme with a suitable mnemonic to encourage innovation and to formalise the assessment of suggestions. Such schemes can be made into excellent motivators and one has only to look at those instituted by Anglesey Aluminium (3) and British Gas (4) to get a clear indication of their value. In addition, there are a number of awards made by Government and industrial bodies which whilst outside the scope of suggestion schemes create an innovative atmosphere.

If lessons have been learned they are firstly, that motivation is not easy whether by paper or person. The task is a somewhat thankless one in that until the particular liquid fuel shortage appears people at all levels have little time to spare for the refinement of everyday energy usage. Secondly, that in directing the effort a "broad brush" approach should not be used. The effort should be directed at the manager who is accountable for the major energy users. The manager in turn motivates the operative on the ground controlling the everyday operational cycle. When so motivated results will follow.

CAMPAIGNS

Measuring the Results

In any system required to bring results from everyone the campaign is an almost universal method. Classics from the past are World War Two "Dig for Victory" and the annual National Savings Drive in aid of a particular military arm. The problem can be seen as one of assessing the results. The former is far harder to measure than the latter in that special exchanges of money for paper (stamps/certificates) are easier to measure than the yield per hectare given to growers and the efficiency with which they grew. Equally true of this is a campaign for energy saving. Metered and measured sources can be registered and accounted but particularly in liquid fuels their efficiency in the hands of the ultimate user cannot.

The National Department of Energy "Save It" campaign was brought to Thames shortly after it was launched. Having an established Working Party the various aspects could be considered but the heart of the strategy was that a 10% saving ought to be achieved with good housekeeping. The very reasonable assumption had been made that with everyone's attention turned to energy use that which had been ignored as a source of loss for years would now be corrected. For example it was in fact astounding to note the number of industrial installations with unlagged steam services. The "Save It" campaign did, and still does, have the effect of ensuring that the need to conserve energy is brought to everyone. Whether or not effort is being made is not possible to measure and, if it were, would the cost and energy use expended in the devices manufactured for measurement outweigh the final gain? Such is the problem of assessing a campaign.

"Save It" and other national means have not been subjected to measurement for internal results and have generally been thought to be most useful in creating overall awareness in those who do not influence plant design and operation. It is in the latter area that a particular form of "in house" or specialised industry form is most beneficial. Therefore, national efforts are seen as useful in the sphere of overall awareness but of limited benefit without extra effort in the particular places of energy utilisation.

Effects

The first part of internal work is Divisional activity stemming from their management team and Energy Manager. Amongst those that have occurred are the familiar and often used ones directed at liquid fuel conservation in the form of petroleum spirit. These generally take the form of stickers and slogans placed within vehicles to extol the benefit of less throttle, less energy, or similar. Again difficult to measure in terms of results but effective in keeping conservation matters uppermost.

Response

Recognising that the energy management function had evolved with the national and international scene rather than having been directly instituted with a formal procedure and records from the outset of the Authority it was decided that a base situation should be determined. In order to achieve this objective it was agreed, following a report and recommendation, that the Director of Operations should call for a 5% energy usage saving in the year ending 31st March, 1980. The setting of such a target would have three main effects:

1. supporting the national call for a reduction target put out in 1979.
2. establishing a base position for the future.
3. determining the limitation and whether or not efforts previous to 1980 had rendered some areas fruitless for further reduction.

In such a campaign or target situation it is obvious that those who have in any event been efficient will have the greatest difficulty to making a further reduction. In this exercise those who get the best results should in fact be regarded with suspicion! Nonetheless the institution of the camapign meant that people's minds would once again be concentrated on the energy scene. Again the financial problems beginning to emerge in 1979 meant that the Authority's accountants responsible for revenue saw the financial benefit from such an exercise. To them the possibility of reducing the revenue budget allocation by some £850,000 was a powerful argument for the proposal. Even if the base position were maintained from the previous year a substantial benefit would accrue.

Summary

Therefore the campaign is seen to have its place within the energy scene but experience to date suggests without doubt that "broad brush" efforts stimulate all and are probably best used when a particularly notable event has occurred, i.e. loss of an oil producing source or change in financial policy and that efforts with measured and quantified results need to be part of internal working and administration. It is perhaps sad to reflect that it has been found that even at high levels there can in some areas be found those with scant sumpathy for a campaign which will make an incursion into their time and working methods. Energy Managers should learn to identify these.

RESULTS

Tariff Work

In looking at the results and their achievement the initial area is normally in tariffs. Tariffs with demand charges related to time or period of supply are commonplace in charging for electrical energy. Thus every Energy Manager has been encouraged to look carefully not only at terms for affording provision of energy but also the associated operational cycle which if it is changed will alter the amount charged. The relationship between tariffs and energy is often argued to be merely a matter of money but it must be borne in mind that the tariff for a fuel is normally structured to penalise inefficient use. Therefore whilst the user may see the benefit in money the supplier will see the overall benefit in efficiency of the energy source i.e. there would also be a saving in energy.

Tariff monitoring and changes have taken place since the outset of the Working Party and it is considered that alterations in operational methods, negotiation and changes to alternative known tariffs had saved some £200,000 by early 1979. The problem with cumulative figures for such activity is that a tariff change which yields £100 in year one lasts in real terms for as many years as the plant supplied continues to operate in the chosen mode. For all normal purposes this however is only accounted to the initial year. One point worth making in respect of tariff negotiation with public undertakings particularly Electricity Boards is that the Acts (5) creating them prevent "undue preference" towards individual or group consumers. What in effect this means is that you must prove the benefit to the supplier of the proposal being made for special terms. The classic case is of course peak load removal or "load shedding" from the National Grid system.

A generally accepted further measure is that of monitoring incorrectly rendered accounts. The point is often lost that money raised in loan and used to pay additional amounts above those invoiced attracts interest. Therefore a record was instituted in the annual returns to monitor the amount of incorrect accounts. By early 1979 a figure of some £300,000 has been recorded in excess of that owing at the due date. To have raised such a sum or loan for even 7 days would have attracted interest charges of £1000 apart from the administrative time involved.

Campaign Effort

The results of the 5% energy reduction campaign are at the time of writing this paper still being analysed but one significant result has emerged. A concentrated effort was made to reduce the energy input to New River Head, the Headquarters of Thames Water. As mentioned previously it is beneficial for the effort to start at the top! Based principally on oil fired boilers for heating purposes it was stated before 1979/80 winter that steps would be taken to conserve fuel and a broadsheet sent to each staff member on the necessity for conservation and not to expect temps. in excess of 60.8F in offices for the first hour; (the minimum prescribed in Offices, Shops and Railway Premises Act). Further, that some discomfort could be suffered due to lower temperatures accompanied by requests that prudent use was made of lighting and other small power services. The result of this action was a reduction of 19% in liquid and 9% in electricity consumption over the preceding year. Allowing for the correction between the winter temperatures of the two years in question the result was within the required target and indicated that a saving effort could be made.

It is anticipated that further examples and areas will be revealed but the figures will require to be related to climatic conditions and other operational factors to give a reasonable comparison with previous years. Clearly, the requirement to afford service on an annual 24 hour day continuous basis necessitates use of machinery to the demand experienced which is dependent upon the weather cycle and this cannot as such be controlled for energy conservation purposes.

In the process of studying plant many systems have been examined and whilst an absolute total figure cannot be given as measurement by instrument could not be made available, the following plant has been modified or altered in operation to give a lesser fuel consumption:

(i) lighting levels
(ii) heating controls
(iii) boiler replacement
(iv) automatic controls

Revised or Remodelled Machinery

A vital part in achieving results is that of remodelling or renovating plant. Here there is an ideal opportunity to remove "energy eaters" and it would probably be best illustrated by examples.

1. Remodelling of machinery. - A 105 Ml/day pumping station in North London has been re-designed to provide machinery to eliminate throttling occasioned by differing distribution zone requirements from a single source. The consequent saving will be in the order of 200,000 KWhrs/Annum.

2. Revision of Stores Lighting. - At a stores Depot the lighting was revised to give the requisite level utilising sodium lamps. The consequent power input was reduced by a third and the saving in running cost was estimated at £1000 in the then current (1976) prices. (6)

3. Coal/Electricity Conversion - The Conversion of an existing nominal 66 M Litre/day capacity water treatment and pumping station from coal fuel steam plant to straight forward electricity consumption from the National Grid will reveal a maximum reduction of 112 MWhrs per day after allowing a Grid transmission efficiency of 30%. Whilst a plant of this nature would, due to the antiquity of its pumping machinery, have to have been remodelled in any event the figures show the reductions that are to be found with remodelled plant.

Summary

It is perhaps significant that the overall scene of results and saving experienced since 1974/75 is not known and in the authors' opinion could not be. The evolution of the energy scene, the development of the management emphasis gradually over ensuing years, has meant that a detailed step by step record would not have been instituted. However, the intention following the establishment of a base position is to move forward with a system that will correlate results of efforts in a common unit base.

EXPERIENCE GAINED

One of the first lessons learnt in the life of the Working Party was that there would be no award granted for any increase in bureaucracy. Whatever the justification there was a strong resistance to demands being placed upon Divisions for information. It was not the authors' task then, nor is it now, to opine on that aspect of their own Authority but it was clear that any call for other than the most concise details leading to information that would be of direct interest and use would be greeted with hostility. Therefore anyone wishing to start on a system for monitoring both energy use and conservation must ensure firstly, that they have consulted those who will provide the data and secondly that the data provided can be beneficial in aiding the everyday task. Those seeking information for its own sake are damned from the outset. Thus it must be recognised as difficult to identify the smaller, (but nevertheless vital), gains as the system is refined.

In seeking to promote energy conservation there is no place for the "stick" and in the public sector it is extremely difficult to offer "carrots". The inducement of a reward is often ignored particularly where the work load is stretched on the ground. A perhaps dramatic example of this was the 1976 drought. Anyone attempting any changes in operational working in order to achieve an annual prize would have received short shrift from those attempting to use every piece of machinery to meet a sometimes impossible demand. Here is a paradox from water pumping in that load factors were so high in 1976 on water pumping that there was in fact a comparative saving in the cost per unit of electrical energy used. Conversely to have issued a managerial edict at this time that a level of energy must be saved would have been quite impractical. Only removal by "force majeure" of the energy supplies would have wrought any change.

Therefore both inducement and directives must be carefully measured against the period in which they are proposed to be used.

There are in managing energy as with any other system the inevitable personality problems. Probably the worst of these comes from the "dyed in the wool" person who will manage to find every conceivable reason for doing nothing. Probably suffering the resistance to change that comes with age this type of person needs to be identified by the Energy Manager. Suffice to say there are only really two ways with which this problem can be dealt. Either seek a change in their duties and responsibility or by action elsewhere demonstrate that results can be achieved.

Whilst considering incentives it is also a problem for a public utility to offer sufficient reward. In offering a prize for an Award Scheme at what level can it be pitched? When considering this in conjunction with the Director of Finance it was clear that awards could be made but to be acceptable they would have to be at a level which would be acceptable to Authority Members and public auditor alike. Further, that they would require to be comparable with existing schemes. To summarise it was considered that the award offered should not exceed the award gained for long and meritorious service.

Ever present as a problem to conservation is the level of service that must be afforded to the consumer. Here any proposal for action must walk a tightrope between operational need and energy efficiency. Much has been written of balancing machinery over the known, or projected, figures for a plant but one particularly difficult climatic change can upset even the most carefully prepared plan. The more obvious of these are droughts and storms. However, there are benefits to be gained from studying the conservation levels that would ensue from either questioning the need to provide for example water at the tap for 24 hours a day, or alternatively seeking a system which will in effect "buffer" energy consuming units against a 24 hour weather dependable demand. Certainly in Thames the latter has been considered the preferable option and will receive further attention in the future. (7)

Another area that must be economical and established as a suitable ground for gaining implementation of conservation is the capital development programme. Certainly at present capital expenditure is under almost microscopic examination. The basic consideration is simple and that is that badly worn or antiquated machinery wastes energy. An example discussed in recent months was that of a sewage screening system run continually rather than on the six hour duty period required. Experience had indicated that to attempt a period related to process demand had led to an unacceptable failure rate. Running the machinery to this pattern required an excess use of 72,225 KWhrs/Annum at a cost of £1,733.

Again leakage from mains has been a much discussed and commented upon subject. To indicate the possible scale it is calculated that if some leakage estimates for London are correct a reduction of 10% would save 22 MWhrs in energy and some £500,000 in cash per annum. The degree of renewal or leakage tracing warranted by capitalising the saving is of course arguable but the fundamental principle is to ensure any capital expenditure scheme has the energy consideration stated and preferably seek to have this included in whatever procedure is used to evaluate the worth of the proposal.

Organising energy management with persons who in any event have a full time separately prescribed post is not an easy task. Accepting that any decently organised undertaking would have ensured its management and engineering staff paid attention to plant consumption as a direct derivative of its efficiency (indeed that is in any event an engineer's responsibility) to take out energy as a particular subject or study is not as straightforward as it may appear. In some ways this can be compared with the safety scene. Before the enactment of the Health and Safety at Work Act well organised bodies had safety under control as a specialist task but others were content to leave it as a nicety unrelated to either profit or getting the job done. The force of law soon ensured that everyone had to pay the same degree of attention, or be penalised. Certainly one would never wish to see such a situation in energy but once beyond the immediate and obvious gains the Energy Manager has an uphill task. To go into any system and evaluate its energy use requires a great deal of time and detailed study. Here anyone considering the refinement of energy conservation must consider their working environment and what proportion of a person's or persons' effort is required to meet the objective. If it is decided to incorporate the management of energy in the everyday structure along with other tasks it is vital to ensure that there is a link between the Directors and local management to ensure energy is given,and keeps, its rightful place. Thames has benefitted from the interest and support of all levels of staff throughout the organisation starting at the top. Although this is undoubtedly not the only way to deal with energy it is one that is considered to have been successfully applied.

FUTURE DEVELOPMENT

National Action

Through the Department of Industry the attention of Thames was drawn to the in depth studies by the Energy Technology Support Unit of major energy using industries. The Energy Technology Support Unit(E.T.S.U.) is a group of scientists and research specialists based at Harwell and is a branch of the Department of Energy. The expertise of such a group directed across the whole water industry in this country with the joint support of the Department of the Environment and the Department of Energy looked to be an opportunity which should be grasped wholeheartedly. In the event, the foresight and enthusiasm that existed in the Thames Water Authority was not unfortunately, sufficient to carry the majority of the rest of the water industry along nationally and the opportunity to indulge in a national survey, hopefully partly funded elsewhere, would appear to have been lost. Thames is continuing its discussions with E.T.S.U. with a view to a limited survey being undertaken of Thames. This however will not attract the financial backing from government which would have been forthcoming for a national survey. Thames has been successful in persuading the N.W.C. Training Division to bring Energy into their 1980/81 National Training Programme. Although this is in the form of a two day seminar pitched at top management, courses for other levels of management are planned. It is anticipated that these courses will continue in a broad based fashion and be held at intervals which will enable those concerned to review both the energy scene and methods of conservation. N.W.C. Training Division are also considering incorporating a session on energy conservation in their senior management and technical courses.

Further Campaigns/Targets

From what has been undertaken and learnt so far it is felt that a broad or wide campaign will not suffice. These are in any event generally mounted nationally at the most apposite moment and cannot be used on a local basis. It is now considered that the future must be based on particular types of installation. If one accepts the law of diminishing returns must apply then only breaking the problem down to specific areas will assist. Thus, future campaigns will concentrate on a particular area of utilisation, e.g. heating of operational buildings.

Until the result of the present target saving campaign has been analysed a future target will not be set. Effectively the 1980/81 year will be of consolidation and as with campaign work it is expected that targets will prove to be most beneficial if aimed at specific areas. Again the target is likely to commence with a review of operational methods and their potential benefit rather than a set of mathematical percentages; Targets will be used however, because they have the great benefit of focussing the mind on a particular objective.

Novel Methods

The so called "novel" methods of energy production have been looked at from time to time and this will be so in the future. Many ideas and schemes have been put forward but have so far failed on either practical or economic ground. Probably the greater scope lies in wind, solar and heat pump forms of development. At present the first is facing aesthetic problems and the third whilst having been subjected to much development still requires further work to make abstraction from low grade sources economic. Thames is watching the situation closely and is eagerly awaiting the classic "break through". Most promising is the second and trial installations are being surveyed.

Design and Development

It is quite obvious that any future programme could not ignore this aspect. Design is an area of constant change and whilst it is part of any professional engineer's responsibility to use all sources, including energy, wisely, the overall effect of a design can often be buried or forgotten in energy terms between the various disciplines when developing a project.

Changes in energy economics will have to be taken into account in future development. Total energy schemes and schemes for waste heat recovery are becoming viable where once the economic considerations made them hardly worthwhile. Pricing policy is clearly aimed in the fuel industries at ensuring efficient utilisation and future work must be directed at having included with designs an overall assessment of their energy implications and the steps that have been taken to ensure the best use has been made of energy sources.

In this respect it would be hoped to progress towards bringing the Energy Manager formally into the management structure so that future needs are considered from the outset as part of the process of evaluating capital project proposals.

Review of Present Plant and Operation

This is part of a continuing exercise. Clearly with limited resources to review the energy aspects of the modus operandi of all plant and methods of operation within an Authority the size of Thames is a mammoth task. Much work has been done to date but a future programme will be encouraged to include:

1. revision of raw water stocking, and hence pumping cycles. (7)
2. service reservoir provisions and operations to give high pumping load factors. (7)
3. assisting programmers to minimise mains leakage.
4. examining methane gas utilisation.
5. energy involvement in alternative methods.
6. utilisation in buildings.

Whilst much of such a programme may be looked upon as obvious it has been found that methods that have been used for many years were implemented when energy was cheap and, in relative terms, plentiful. Therefore a review of this nature must not only consider conservation but also whether or not future energy supply will provide the scope and security of operation required.

Management Development

The creation of a Steering Group has been approved and it is hoped to use this method for bringing out guidelines originated from Director or Management Board Level. The energy scene has over recent years been one of continual change. With limited resources a guiding hand on directing detailed effort on the ground is seen to be essential.

Beneficial to the provision of a Steering Group to give policy guidelines would be the development of an Energy Conservation Budget which would make provision for expenditure on both plant efficiency improvement and research. Often plant cannot be improved within conventional capital expenditure budgets until a major scheme is implemented. However, work could be undertaken if identified for the separate energy conservation purpose in its own right.

A final vital part of central direction is to ensure that within the 1001 other things that are undertaken within a Water Authority energy is not last and retains its place as being the most vital factor in continued future operations.

ACKNOWLEDGEMENTS

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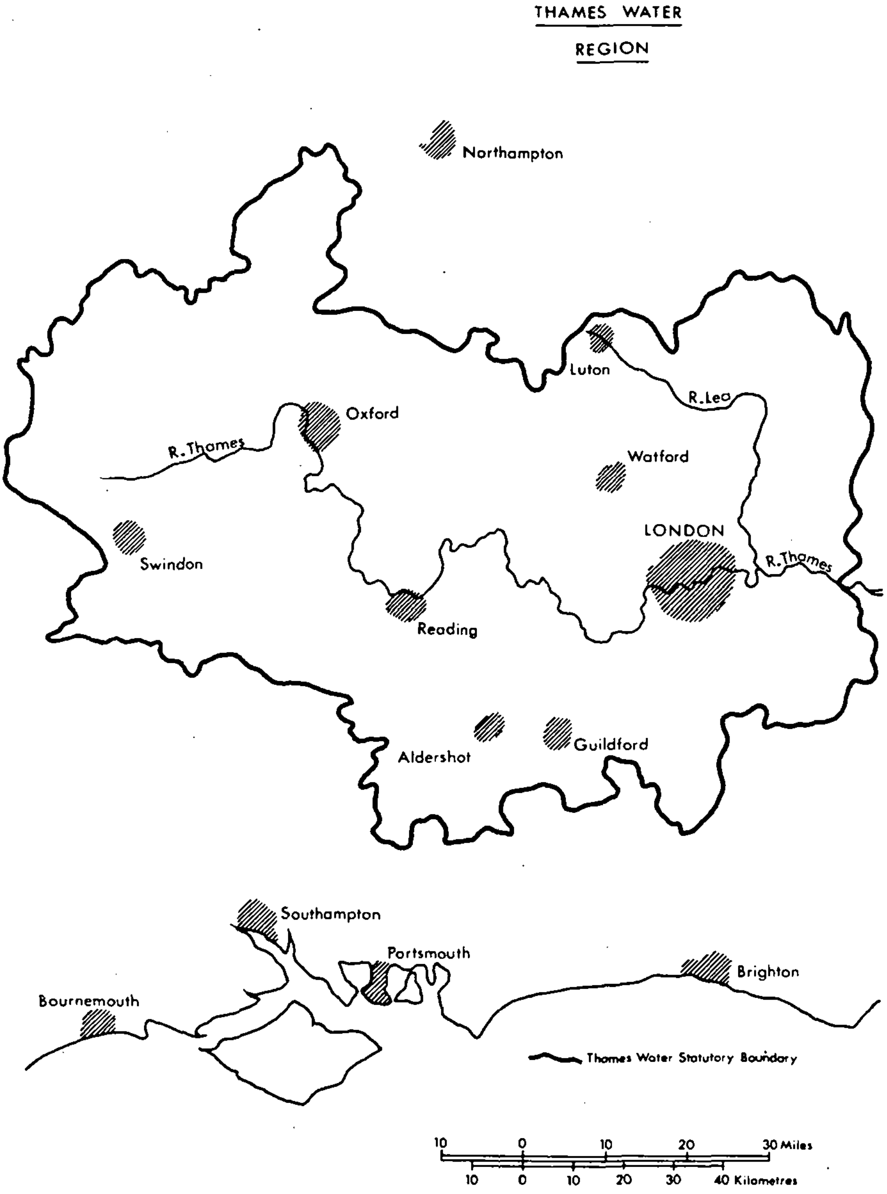

Fig. 1 — Thames Water Area

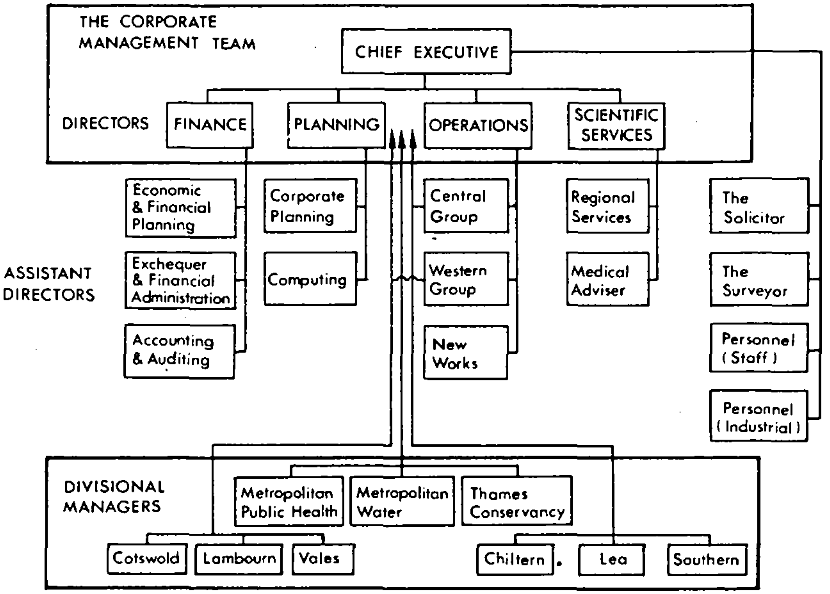

Fig. 2 – Corporate Management Structure

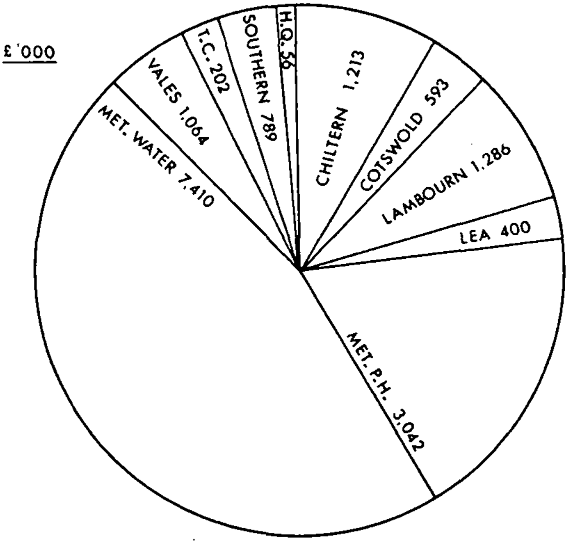

Fig. 3 – Energy Expenditure by Division 1978/79

DISCUSSION

Authors' introduction

Mr Wright introduced the paper by saying that its theme was not 'Thames Water was the greatest' but rather 'Thames Water warts and all'. Indeed, quite often more could be learnt from mistakes than from successes.

In October 1974, when the water industry was still grappling with the aftermath of reorganization, the Management Board of Thames Water had decided that an engineer and an accountant should get together and examine power tariffs throughout the region. Thus, initially they had been concerned with ensuring that the right price was being paid for energy and it was not in their terms of reference to consider conservation, alternative energy sources, etc.

The divisions, who supplied them with information and would have to implement any changes resulting from their studies, had been given a large amount of autonomy, and management styles varied considerably from division to division. How then could they, at regional level, ensure that divisions were obtaining value for money in their energy purchases? They had considered a number of ways of organizing their task.

1. Centralize: bring all information to the centre and have one Regional Energy Manager.
2. Bring in an expert. There were very good arguments for doing this. The expert called in from outside would be detached from internal politics; his costs would be apparent, and, therefore, psychologically he would have a higher value than in-house staff, and more notice would be taken of his reports; and he could bring expertise from other industries and widen the knowledge available to the organization. There were disadvantages, however. Management often failed to recognize talents and expertise within its own organization. Staff noticed this, and morale could suffer. Furthermore, critical self-examination was often the best kind for management and staff alike; and uninformed experts could be disruptive when they were in an organization, and leave mistakes in their wake when they left.
3. Decentralize: they had finally opted for the engineering concept of self-regulation with the divisional Energy Manager as the 'flying ball governor'.

It was no use giving someone a job without the tools and authority to carry it out. Here they learned from their mistakes as they were slow, having nominated an Energy Manager in each division, to give him sufficient authority to carry out the responsibilities which they had placed upon him.

The Working party consisted of the two Director's nominees plus the Divisional Energy Managers. It was not a talking shop but an outward-looking group which sought new ideas and techniques and exchanged experiences. It was also a co-ordinating, monitoring, and policy recommending body.

When it came to setting targets and monitoring performance, the accountant and engineer relationship was crucial. They decided upon key measures of efficiency which could be applied to every installation throughout the region. These were discussed and agreed at the working party by those divisional representatives who would be responsible for implementing them in their divisions. Bureacracy and form filling was kept to an absolute minimum, and not only in the working party but also at divisional level accountants and engineers were encouraged to work together. Understandably, standards varied from division to division and action was needed to support those divisional energy managers who were less successful in implementing working party policies. These problems should have been recognized earlier and corrective action taken. Some of the shortcomings were not revealed until a division by division visit was made to assess the effectiveness of the implementation in each division and to explain the policies to each divisional manager.

The problem was to convince management which was tackling day-to-day crises that sometime in the future supplies of oil would possibly run out, and as that time approached the supply and demand equation would cause an astronomic rise in the price of all fuels. Management was sympathetic but because it was a future problem it quite naturally was a low priority when set against day-to-day crises.

Management could understand the importance of value for money and ensuring purchases were made on the right tariff but to go further and consider alternative operational cycles or to invest scarce resources in, for example, insulation of digesters was quite another matter. Even with the enthusiastic support of top management it had taken considerable effort to keep up the momentum. The crises of shortage of supply and astronomical price of fuel had not materialized yet. There had been gluts of fuel and although the price had risen it had been a relatively modest increase. In fact, because of inflation reducing the real price of energy the average price of all energy was only 35% above its 1973 level.

Mr Thomas said that in summarizing the latter half of the paper he would comment mainly on what had happened at the active level and what it was hoped would happen in future.

The results began with tariff work and this was a continuing exercise. However, as those engaged in this work would know the 'law of diminishing returns' applied. The experience of others in attempting to attract lower rates as a reward for load management would be welcome. Experience to date suggested that there was a difference of enthusiasm between the producers and distributors in this time of recession.

Setting out with a target and enthusiasm was all very well but attempting to track, measure, and evaluate in the space of twelve months was a daunting one. However, the valuable lesson had been learnt that smaller areas of attack were necessary if the main battle was to be won.

Revising or remodelling machinery was an obvious area to tackle, but even so it was surprising how many new possibilities had emerged. Comparatively cheap, powerful systems were becoming available as more microprocessor systems were developed. In this respect both tariff and energy use could be linked with many tariff-orientated applications in which base and intermittent loads could be identified and switched to alternative regimes for the purpose of load management.

A problem which had to be faced was the scope which anyone had for conservation in providing, as a matter of legislation, a year round continuous service. Many devices used to economize in cyclic industries were not available to them. After all, the power industry cynic would claim and quantify as savings the effects of power industry supply failures and the like in the number of therms or mtce that had been saved! Likewise a sudden removal of water supply between 23.00 and 07.00 with a request to 'fill up all available receptacles' would be ideal to achieve 10% or more conservation in that part of the industry! This was clearly not possible and that was why water stocking in raw and treated water reservoirs was given a prominent place in future development.

The whole purpose in presenting the paper was to give to others the benefit of an experience in getting to grips with energy management. Whether or not this was of value was for others to judge but certainly the work of the last six years had brought a wealth of understanding of the problems of extracting energy as a subject and then applying a management technique that will bring economic benefits.

At present some 340 mtce were used annually in the UK. This represented Wembley Stadium filled 400 times by coal or 120 sacks for every man, woman, and child in the UK. That level was required to maintain present living standards, and 95% of this figure came from finite resources. By the year 2000, 80% of known finite resources will have been consumed in less than a lifetime. Articles basic to our lifestyle, all took power to produce. Society was, in effect, fed, clothed, and transported by consuming energy. At present rates of use these could only be continued to be produced from finite fuel resources if conservation was practized. To produce the leeway needed for growth, greater efficiency, and conservation was, he believed, imperative. The alternative was an unacceptable negative or zero growth which some believed equal to death.

Verbal discussion

K.J. REYNOLDS (Lee Valley Water Company) opened the discussion by quoting the phrase: 'conception is one of the easier yet most important stages in the achievement of any objective'. That objective so far as the authors of this paper were concerned was initially not so much to save energy as to save that other scarce commodity - money. He would not wish to detract in any way from the value of that objective. It was all the more remarkable when one considered the enormous range and numbers of problems which must have beset the Authority which, in 1974, had only just come into being.

The authors described page 5.5 the role of the Working Party and the contacts which it made with a wide range of outside bodies. He was somewhat disappointed that it was not thought appropriate to exchange ideas with the seven progressive water companies within the Authority's area, but perhaps they had all been a little shy in coming forward at the time; after all it was in 1974!

Although the first objective of the Working Party had been to save money (and £200000 saved up to 1979 was a fine achievement) it was clear from page 5.10 that saving energy itself had now assumed a higher priority. Saving energy and/or money was not easy for any part of the water industry because, as the authors had pointed out, most was used in pumping water, sewage, and storm water and there was not a great deal they could do to vary any of them within the normal restraint of capital expenditure. Despite this, however, this area must be the most fruitful source of savings. Had the authors any comment to make on:

(a) the application of power factor correction?

(b) pressure reduction in boosted zones especially at night?

(c) controlled outflow restriction from service reservoirs at times of low demand to reduce pressures and thereby quantity and leakage?

(d) imposing high charges for hose and sprinkler use including obligatory metering of all properties using these facilities so as to reduce peak summer demand?

Turning to future development, it was indeed sad to learn of the less than enthusiastic reception of the water industry towards the Energy Technology Support Unit. Could the authors expand further as to why this was so?

Noting reference to novel methods of energy production and use reminded him that when Lee Valley Water Company was formed from several small units in 1960, one of the early tasks was to determine the fate of a wind driven pump at a remote elevated site. That took very little time and it was demolished. Today, he thought, they would have much discussion before doing that, and would almost certainly retain it.

More usefully perhaps they were successfully employing solar cell generation at another remote tower site to provide signal power for telemetry equipment, thus saving the prohibitive cost of affording public electricity supply to the site.

R. HUNTINGTON (Wessex Water Authority) said that energy management wouldn't just happen, nor would it be effective if a broad brush approach was used. It required attention to detail and, perhaps most important, getting key staff's attitude of mind right. Having got attitudes right they had to be kept tuned to the correct wave-length and there was no better way of doing this than providing good feed-back of information so that staff could see the results of their efforts. Success bred on success.

He then gave details of some energy-saving schemes he had been involved with.

Automatic pressure control by telemetry links had reduced consumption in a supply zone by 10%. The zone was in Weymouth, included 12,500 properties, and had a consumption of 10 Ml/d without automatic pressure control. Normal pressure at the key monitoring point varied between 18 m and 30 m, but was maintained at approximately 16 m when controlled. Minimum night flow was reduced from 2.2 Ml/d to 0.8 Ml/d which was equivalent to a reduction from 7.3 l/hd/h to 2.7 l/hd/h. It was interesting to compare these figures with recently published minimum night flow figures for the UK which ranged between 2 to 12 l/hd/h. Controlling pressures at lower levels also meant that there was a reduction in the incidence of bursts which was important in an area where the distribution system was largely 60 to 100 years old.

Pumping costs had been reduced by drawing up reservoir level and distribution pressure control curves relating to least cost operation then feeding the curves into the computer controlled telemetry for predictive monitoring. At one pumping station a cost saving of 20% had been achieved.

Oxygen consumption at a sewage treatment works treating up to 45 Ml/d of sewage had been reduced. Up to 10t of oxygen a day was used to achieve effluent of the required standard, but by careful monitoring of effluent quality and dissolved oxygen in the aeration units, it had been possible to reduce oxygen usage in certain periods by up to 4t/day. As oxygen cost about £55/t such fine tuning was well worthwhile.

Results such as these were good motivators, but they must not fall into the trap of trying to get staff to take two bites where only one existed. In many areas of energy conservation, if the first attempt was done properly, there might be little or nothing left for further economies, and any further call for improvement could be counter-productive as staff enthusiasm might be lost. They should not put in more resources than could be got out.

Finally, he turned briefly to the question of new works design. A new realism was creeping into design at last, but more impetus was needed. All too often they had been carried away with the desire to cater for the year 2010 plus and used planning figures which had a little bit extra added at each stage of the process, just for safety; then extremes were examined, just to make sure the proposed system would cope with all eventualities. Throw in the use of pipe friction factors based on, say, 30 years deterioration and out came a specification for pumps and works which had little relation to what was really needed in the first 5 to 10 years of operation. In consequence, they could pay heavily in this period due to very low operating efficiencies and had scarce capital under-used. Recently two quite major schemes had been examined; one six years after commissioning was still only operating at 20% of design capacity, while the other was running at 30%. Both were giving trouble, because the equipment was incorrect for the low work load. There was a need to examine in more detail economic means of taking care of long term needs and rare events, and where possible provide far better phasing of works and equipment. Get the balance right, and perhaps schemes would perform as they were intended from day one and not be an embarrassment to designers and a drain on operational staff's budgets and patience.

J.E. THACKRAY (Severn-Trent Water Authority) said that he was very pleased to have been asked to make a contribution to the discussion of this paper. He had found it particularly fascinating and commended the authors for their courage in setting out so fully the administrative problems and processes of the Thames Water Authority in managing their energy requirements. The Severn-Trent experience was in some respects very different from that of the Thames Water Authority. First of all, Severn-Trent expected to be rather more affected by the results of exploitation of new energy sources than by changes in energy costs themselves. Three major new coal developments were projected in the region:

(a)	Vale of Belvoir	(around 500 Mt)
(b)	The South Warwickshire	(around 500 Mt)
(c)	The South Staffordshire	(around 150 Mt)

It was not yet clear how much of these new coal fields would be exploited but the impact on both the authority's existing piped services and its environmental protection functions would be considerable. In addition new services would be required for production and the coal itself would be converted either at Power Stations or new coal gasification plants into other forms of energy and this would also give rise to major work for the Authority.

In determining its future plans Severn-Trent had taken note of the fact that financing costs had the biggest single impact on charges to customers, being 44.5% of gross revenue expenditure in the last financial year. These were followed at a lower level of 24% by employees costs. The bulk of Severn-Trent's efforts in optimizing its use of resources had so far been spent on these two items. However, among the variable costs associated with the local operation of works, energy costs (in particular electricity costs at 4.9% of total costs) became a much more important variable. Other fuels were important locally but formed only 0.7% of total costs.

Comparison of energy costs division by division in Severn-Trent had revealed that water supply costs were very variable and that the variation was principally governed by the type and location of source works. For instance, in the Tame Division, benefitting from gravity supplies from upland reservoirs, energy costs per person supplied were exceptionally low. What was surprising was that for water reclamation and sewerage, energy costs varied as widely as they did for water supplied. This could not be explained so readily in terms of the basic geography of the areas and the relationship between gravity and pumped systems. It seemed likely that a major part of the variation could best be explained by the relatively high unit energy costs of providing sewerage and sewage disposal facilities in rural areas with small works and the much lower unit energy costs for providing the same facilities in heavily urbanized areas where economies of scale at large works were practicable. Detailed works-by-works investigation was required. So far it had revealed that costs could be significantly reduced in some cases by relatively simple changes in operating practice or by.cost effective and relatively modest investment in modifying plant.

They had also found that, contrary to popular belief, electricity costs for water services (in the Midlands at least) had not increased faster than the general rate of inflation over the last seven years if the current tariffs were compared. It was therefore important not to get the energy conservation issue out of proportion with other areas of good operational management. In Mr Thackray's opinion it was reasonable to assume that the Electricity Boards knew their business and set tariff structures in relation to their total energy costs, including those implicit in building and maintaining generating capacity as well as those associated with actually producing electricity on an hour-by-hour basis.

Within that general situation Severn-Trent was not complacent as to its own record in energy conservation, indeed, it was concerned that energy conservation over the past seven years had probably not been as effective as it might have been. Provisional analysis showed that not only had payments for electricity risen in cash but they had also risen in real terms at a rate somewhere around 2½% per annum. This rate was higher than the rate of growth of throughput to customers. In part this arose from the increasingly higher standard to which the Water Authority was working, particularly in the area of effluent treatment. Nevertheless, some of the increase probably had to be attributed to a growth in leakage from the water distribution system, with a consequent net dissipation of energy if this leakage could economically be reduced. This issue would be given increasing attention by Severn-Trent, and Mr Thackray asked whether Thames or any other water authorities could produce similar, or comparative, analyses.

D.L. WALKER (National Water Council) commented on the suggestion that a 'Save Water - Save Energy' campaign would require a decision at national level. While he supported the general sentiment, he felt the authors had recognized the drawback already: unmetered customers would see no reward for their efforts. Most water authorities were now interested in water economy, and energy economy would go hand in hand with that, but he would be glad to see the water industry devoting more attention to the proper understanding of distribution losses before preaching water economy to other people.

The authors had been disappointed at the apparent lack of enthusiasm for a national survey of energy use in the water industry, but Mr Walker had understood that outside funds were not in fact available. However, they were to be congratulated in getting energy conservation into management training and he hoped this would attract support. Mr Walker suggested that the publication of case studies was an effective method of promoting energy conservation. The Water Research Centre News had described a simple and effective example in which Severn-Trent WA had insulated sludge digestion tanks. Perhaps the IWES Journal would be able to publish important case studies.

H.G. SIMS (South Staffordshire Waterworks Company) pointed out that there had been little mention of the monitoring of the results of the various energy savings systems outlined in the papers, and explained a system which had been developed within his Company to provide a management control.

On an annual basis all fuel consumption figures were expressed in kWh. For 1979 the total fuel consumption was 116.5 x 10^6 kWh at a cost of £2¼m, i.e. 1.9 p/kWh. The indications were that this unit change would increase by 27% in 1980. The fuel analysis showed that electricity consumption was 90% of the total, 33% of the electricity being consumed at Hampton Loade Pumping Station on the River Severn. Every litre of water supplied by the Company had to be pumped and in some areas repumped. The message was; no electricity and no oil meant no water.

The importance of high load factors had been stressed in an earlier paper and a system had been developed to monitor these at thirty source stations and to derive an overall 'operating factor'. At the end of each month, for each station on a maximum demand tariff, a hypothetical electricity cost was calculated assuming that the number of kWh consumed had been consumed at 100% load factor. This cost was substracted from the actual cost and the difference regarded as money and power which could have been saved. The power would be saved mainly by the CEGB operating more efficiently. On a monthly basis, figures were prepared for each distribution zone and for the system as a whole.

Figures for the last five years are shown in Table 2. The high 'operating factor' during 1976 was due to stations being shut down during the drought and the remainder operating at a higher than normal load factor. It could be seen that by tighter operational control, the 'operating factor' was gradually improving, eventually a plateau would be reached beyond which it would be difficult to make further improvements. This was because it was impossible to operate at 100% load factor due to plant faults, burst mains, and the necessary regulation of the pumping stations. The amount of money which could have been saved in 1980 was of the order of £40,000. With the limitations of a system which is over 100 years old it would only be possible to claw back some of this amount by a proportional investment.

Finally, a word about variable speed drives. There was no doubt that the variable speed commutator motor was more economical than the thyristor inverter system, even including maintenance costs. The latter system was however ideal for converting submersible motors to variable speed. Such a system has been in use since 1978 and was saving £2,725 of power this year for a capital outlay of £14,160.

Authors' reply to discussion

Mr Wright's response to Mr Reynolds's remarks about imposing high charges for hose and sprinkler use including obligatory metering of all properties using these facilities so as to reduce peak summer demand, was that this suggestion was based on the assumption that there was at present a bank of knowledge on customer activity and response to existing charges. In fact in the absence of universal metering and while rateable value remained the basis of charge the likely response to the type of demand management proposed in the question would remain unknown. Little research had been carried out in this country on the subject.

However, studies of lawn sprinkling in Indianapolis, USA, reported at the American Water Works Association Conference at Las Vegas in 1973 showed that in industrial cities or districts the probable sprinkling load would not be great enough on Saturday and Sunday to offset the weekday industrial load, and in residential areas, or cities with light industrial development, weekend sprinkling loads during hot or dry weather would probably be sufficient to maintain the overall water consumption at a level equal to or higher than that expected on weekdays.

There were, therefore, a number of factors which had to be established about customer demands before assessing the response to charges, namely the 24 hour, weekly, and seasonal demands of industrial users in each water supply sector of the region; the 24 hour, weekly, and seasonal demands of domestic users in each water supply sector of the region; and the relationship of domestic to industrial use in each water supply sector.

Mr Thomas said that he would dwell on the engineering rather than cost aspect, although these, as pointed out during the symposium, were not completely divisible.

Table 2 Load factor and electricity consumption for South Staffordshire Waterworks Company

Year	Electricity bill	Money which could have been saved by 100% LF	Operating factor
1976	£1,335,081	£25,554	98.1
1977	£1,518,447	£36,338	97.6
1978	£1,673,497	£36,879	97.8
1979	£1,968,385	£39,165	98.0

Mr Reynolds had referred to the objective of money saving and that was as true now as when the work had been started. One could understand his disappointment that seven water companies within the Thames area had not been consulted. Having acknowledged this error of omission Mr Thomas extended an open invitation to Mr Reynolds's Company, or any other, to join in the work. A similar problem had been discussed in respect of Local Authority agents and perhaps it was here the clue lay to their overlooking Company expertise and input, for there were some 95 agent bodies who with the best of endeavour could not be attended to out of the limited time available to their Energy Managers. Some selective system was therefore necessary.

Turning to the more specific areas of potential saving, he mentioned first power factor correction. There were good technical reasons for this, which had been well known to electrical engineers for years, and were related as much to power system efficiency as energy conservation. The roots lay in the tariff terms and the adverse effect of poor power factor on the efficiency of the producing source be it public or private. It was surprising to find the number of cases where an energy saving improvement was claimed where all that had in fact been done was to install power factor correction equipment which should have been put in initially as a matter of good design.

The tariff aspect wasone which had changed. At one time, where an Electricity Board had a very high non-inductive loading reflected from its customers it did not impose penalties on those (mainly industrial) who did not concern themselves with poor power factor. However, as loading in non-industrial premises had developed with modern lighting, air conditioning and the like, each of which had an inductive characteristic and therefore a wattless component lowering the installation power factor, it was now invariable that Supply Agreements and Tariffs would demand good power factors and penalize its omission. The fact remained however that power factor correction was a technical matter which should be incorporated in any system design.

As far as nightime pressure reductions in boosted zones and controlled outflow from service reservoirs during low demand were concerned, these were to a degree interrelated and although both were clearly areas in which the potential for energy saving could be seen they must be affected by policy which in turn took into account factors of reliability and location. In London there were very few instances of booster stations run to time or pressure regulating devices. The philosophy had been to make service reservoir provision and develop work from that as described in reference 7. However, outside the obviously long standing and highly integrated systems there lay zones which could be served reliably and economically by a pressure modulated booster. To go into all of the factors and comparisons necessary to compare boosted and service reservoir fed zones would need a paper in its own right. Clearly where reliability was adequate in the hydraulic and control system chosen any reduction in pressure and hence energy imparted by a booster having characteristics designed for the purpose must give a potential saving. In controlling the outflow from service reservoirs during low demand the method of modulating the outflow was the point of concern. That control in this manner had energy saving potential was clear but in turn he was aware, at least in his own Authority, of the problems of seeking adequate control and reliability of the system used to vary the outflow. If the policy criteria one had for distribution reliability could be met then the principle could be successful. He thought it was fair to say that these were areas worth considerable study in the future and the apparent energy saving potential was acknowledged.

Higher charges for hose and sprinkler use were really financial aspects with which my co-author had dealt. However, in reflecting upon a considered reply, he felt it would be perhaps beneficial in purely energy terms, but the quantities of energy involved in this activity as a percentage of the annual demand (some 1% ?) might warrant action when the energy situation was seen publicly to be 'save at all costs' but until then it could well be looked upon as another unwelcome impost from a Public Authority. This was an example of the Energy Manager's ever present problem of motivation.

The response to the survey by ETSU, it was sad to say, had been less than enthusiastic. As with many good ideas (or seemingly so) this was one that did not get off the ground. When decisions were made on a whole industry basis it was often the case that the full reason for rejection of a particular proposal was not known. That was so here, and it might be that it was considered sufficient internal effort could be mustered to undertake the task. Whether or not this was the case still remained to be seen but an industry investment of some £40,000 to £50,000 possibly shared with a Government Department would not seem to be excessive to have an independent view cast of the potential areas of energy saving.

Novel energy sources had been mentioned and here one normally ran up against environmental problems (look at the size and noise generation from a windmill producing only 1MW!) and economic appraisal snags. The Lee Valley Water Company example of solar energy use was very interesting but probably it was only viable because of a lack of availability of a public supply. The power output afforded could deal with instruments and electronics demanding small levels for their operation but were any higher levels required for pumps or power operated valves then he thought it unlikely that the same situation would obtain. Suffice it to say that the Thames Energy Managers kept all novel methods under review and were conscious of the project evaluation criteria militating against a project, where if as said earlier the situation was to save energy at any cost they would immediately become viable.

He agreed with most of Mr Huntington's comments. In referring to paying attention to detail he had highlighted the problem that remained for the Energy Manager after the obvious areas of conservation had been tackled. That was finding out where or if the law of diminishing returns applied. Also, the amount of detailed knowledge that was required to apply the principles in a part of the Thames system as large as London's which had taken centuries to develop was formidable.

In considering automatic pressure control within a system or zone it was vital to study the factors referred to in the answer to Mr Reynolds in respect of booster and service reservoir outlet control. Also, once one was inside a dense city or suburban area with an integrated reticulation system, practical problems arose with supplies for instruments, valves, and other power operated devices needed to monitor and control the system. He had during his career (fortunately not in the water industry) been invited to connect electrical instruments to the nearest street lamp as a source of supply! In addition, such areas which required a great deal of 'off-station' equipment to ensure continuity and reliability of supply raised considerable cost in GPO lines for telemetry purposes. These rates were now up to £239 per annum for one km of the lowest grades of line. Another aspect of automatic pressure control was that having imported the energy into the system it was surely a waste to break that energy down across a regulating device.

It was, of course, undeniable that lower pressures optimized to the system demand could bring reduced pumping energy benefits and less stress on older pipes. Here Thames had these aspects under study from a number of different aspects particularly that of establishing accuracy of flow measurement in highly integrated and elderly reticulations and were seeking to establish where the truth lay in the range of night flow figures quoted by Mr Thackray.

The question of sewage aeration had also been given much attention and here again it was undeniable that much could be studied with benefit in trying to optimize the use of energy against the quality demanded of the final product.

New Works design was a fascinating area. Being engaged primarily in that activity himself he was well aware of the degree of crystal ball gazing which the designer must do. It was very interesting to note the low percentage of design capacity being utilized some six years after commissioning, mentioned by Mr Huntington. Similar instances had occurred in his experience owing to over estimated long term predictions but not to the degree stated. What they were more concerned with was building in sufficient flexibility with pumping machinery to ensure that efficiency was kept as high as possible to the demand and that as demand increased over the years efficiency was still maintained. This generally meant that apart from accurate long term forecasts one must select flexible machinery to do the job. He had no immediate knowledge of Mr Huntington's operational staff but certainly if they were as aware as many were in Thames then his percentage of overprovision would drop dramatically as they saw the impact on their efficiency figures in the future! On the subject of setting saving potential by relating load factors to money this was a yardstick which in fact might bring sufficient pressure on the designer to improve the accuracy of his input figures but for the operational reasons stated it could never be used as a conservation performance monitor. The more one increased the load factor and was encouraged to do so the more energy was used.

Mr Sims had commented on the limited degree to which they had mentioned the monitoring of energy savings systems in terms of results. In fact financial performance was monitored by discussion of annual statistics and this not only derived the per unit cost outlined by Mr Sims but also ensured that claimed 'average' or 'inflation' cost increases by the suppliers had kept within the stated bounds. Also that true comparability existed between the suppliers in their method of charging. In addition the year to year consumption of each installation and hence its performance could be compared. Clearly questions were both asked and answered when variations could not be explained by altered operational circumstances. Normally speaking such statistics were co-ordinated centrally from figures produced in each Division. Figures were known from the target saving campaign and had been discussed. What had emerged was the need to seek the ground for further effort and as replied earlier it was here that time was required for attention to detailed plant or separate study rather than broad statistics which in any event were considered formally within the Division as part of operational efficiency reviews.

It was clear that electrical energy expenditure formed the major part of most undertakings' energy expenditure, and also that major installations accounted for very high percentages of the total. That was certainly true within Thames as could be seen from the breakdown given in the paper. The Metropolitan Divisions account for the major usage and they in turn were influenced by their four or five major filtration and sewage works. The load factor monitor mentioned would equate in many ways to that mentioned by Mr Huntington and would be subject to the same remarks. However, these ways of approaching the problem were more than worthwhile and, so long as one was aware of the pitfalls, very useful in stimulating awareness of energy cost and conservation problems.

Mr Walker had spoken about 'save water - save energy' problems and it was perhaps best left for the moment that the water economy efforts would effectively save energy in their wake. Whether or not funds were available for a national survey of energy use was not known but it was hoped that the 'do-nothing' option would not be the one that would be allowed to stand. It had been reported that perhaps something could be undertaken on a smaller scale. Hopefully this would be so and that this symposium and other events would motivate Authorities to either increase their activity in the field or initiate energy management on a formal basis where it did not exist at present. A further help toward this would undoubtedly be publicity and case study material.

6 AN AMERICAN VIEW: ENERGY MANAGEMENT AT WATER AND WASTEWATER FACILITIES

A. Jacobs*

An overview of recent energy management efforts at water and wastewater facilities in the United States is presented. Topics of discussion include energy optimization of existing facilities and innovative techniques being used at new facilities. These techniques include passive and active solar heating, heat pumps and wheels, waste heat recovery, and innovative methods of sludge management.

INTRODUCTION

Marked changes in the availability and cost of energy in the United States have made energy management one of the top priorities of today's society. In the past few years changes in relative prices of energy, labor and materials (Figure 1) have made it economically imperative for industrial, municipal, commercial, and residential energy users to reevaluate their energy needs to the goal of optimizing and reducing energy use from conventional sources.

The United States is the world's largest energy user - present energy use is approximately 75 quads ($75x10^{15}$ BTU's). This figure will double by the year 2000 if use continues at historical growth rates. Although energy growth is not expected to continue at past rates, energy use in the United States will continue to increase. With uncertainties about the continued availability of imported fuels, our domestic energy sources must be increased. A multi-billion dollar program to increase domestic energy has been launched. However, long term options including solar-electric energy and synthetic fuels production are many years from having a significant impact on existing resources. Available resources such as coal and nuclear power are subject to environmental concerns which will make their rapid expansion difficult.

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TABLE 1 - Energy Sources in the United States (1974).

	Total BTU x 10^{15}	Electric BTU x 10^{15}
Coal	13.2	8.5
Natural Gas	21.7	3.5
Petroleum	33.4	3.8
Hydro.	3.3	3.3
Nuclear	1.2	1.2
Total	72.8	20.3

Wastewater and water treatment and water distribution account for 2½ percent of our total energy use and 8 percent of total electric consumption. These percentages will increase with the construction of more secondary and advanced wastewater treatment plants and the necessity for more sophisticated treatment of drinking water. As a result, increased attention is being given to energy management at our water and wastewater facilities, both in existing and new works. This paper discusses a few of the developments and technologies being considered today.

ENERGY CONSERVATION AT EXISTING FACILITIES

Energy costs, mostly for electricity, are approaching the point at U.S. water and wastewater facilities where they are rivaling labor costs as the highest budgetary expense. Figure 2 illustrates the 1980 budget at the Middlesex County Utilities Authority Water Pollution Control Plant and at the Jersey City Water Treatment Plant. Unless energy management measures are implemented the portion of the budget alloted to energy will continue to increase. Through energy management, energy costs (and usage) have been reduced by over 25 percent at some treatment works. These reductions have been obtained through operating changes and retrofit of existing facilities. Capital costs for retrofit construction generally has a payback period of less then 3 years. The areas that have received most attention are:

1. Reduction of electric demand
2. Improvement of power factor
3. Replacement of equipment with energy efficient equipment
4. Modification of plant operating procedures
5. Reduction of incinerator fuel consumption and recovery of waste heat
6. Use of by-product fuels

The following briefly describes a few examples of energy management at existing facilities.

Reduce Peak Electric Demand

In the United States most electric utilities assess charges on the basis of maximum billing period electric demand (usually maximum 15 or 30 minute demand) and energy usage. Demand charges generally account for over 20 percent of the electric bill. Loads which result in high demand charges can be identified and rescheduled or offset by other load reductions during peak periods. The concept of demand control is basically a systematic approach to scheduling energy use. Demand control does not reduce energy consumption; however, a real potential for cost savings exists. The following example illustrates the potential savings.

At the Schenectady water pollution control plant four 75 kW (100 HP) pumps are only used during high river stages - about 6-8 weeks per year. Most of the time, these pumps are not operating, and even when they are running only one or two are necessary to handle the plant flow. The reliability of these pumps is critical to maintaining plant operations during high river stage, and are therefore exercised once per month. In checking out the pumps all four pumps were started and run for about an hour. Running these pumps together resulted in a demand of 300 kW, which showed up each month in the demand charges. Upon review, the procedure was changed so that only one pump was started each week. Over the four week period, each of the four pumps was exercised, but now the peak kW resulting from the pump check-out is 75 kW instead of 300 kW, a reduction of 225 kW in peak demand billing. At the rate of $5.00 per kW for demand the annual saving (for checking the pumps 10 months per year) is $12,250.00

A number of plants are installing automated demand limiters. Demand limiters are instruments that are programmed to monitor demand usage. As demand approaches a predetermined limit, loads are shut off or automatically transferred to alternate power sources (standby generators) in order of the pre-assigned priorities. The instruments can be easily programmed to reschedule loads to more appropriate times to meet plant needs.

High Efficiency Motors

Over the last few years many manufacturers have introduced a line of premium or high efficiency motors. A 4 to 6 percent motor efficiency can usually be obtained by using these motors. A 5 percent increased efficiency of a 37.5 kW (50 HP) motor operating 8,000 hours per year will result in a reduction of about 19,000 kWh/yr. At $0.05 per kWh the annual savings is $950. The additional cost of a high efficiency motor is about 30 percent or $300 for a 37.5 kW (50 HP) unit. Thus, the payback period for the increased efficiency is 4 months, based on motor replacement.

TABLE 2 - Motor Efficiency

kW (HP)	Industrial Standard %	Average Premium %	Efficiency Differential
0.75 (1)	73	81.6	8.6
3.75 (5)	80	87	7
7.5 (10)	84	89	5
37.5 (50)	89	93	4
75.0 (100)	91.5	94	2.5

Select High Efficiency Equipment

In treatment plants and pump stations in the United States many pieces of equipment, particularly pumps, are powered by variable speed drives. Most frequently, these are eddy current, adjustable voltage, adjustable frequency, liquid rheostat or fluid coupled devices. Figure 3 plots efficiency-versus-speed of these and some other drives for variable torque applications.

At one pump station we recently investigated, three 56.25 kW (75 HP) variable speed pumps are installed. Most of the time one pump is sufficient to handle the flow. This pump has a percent running time-versus-percent speed as shown in Table 3. Using an energy charge of four cents per kWh, the relative operating costs for the various drives are shown on Figure 4. An evaluation for installation of a 56.25 kW (75 HP) variable speed pump resulted in replacement of the existing liquid rheostat drive with an adjustable frequency, voltage source inverter drive. The greater efficiency of the adjustable frequency drive resulted in a reduction of $6,165 in annual energy costs.

TABLE 3 - Percent Running Time Versus Speed for Typical Centrifugal Pump Station

% Running Time	% Speed
10	100
15	90
20	80
20	70
15	60
10	50
10	OFF

The cost of the adjustable frequency drive is approximately $20,000 resulting in a 3 year payback period.

Incinerator Fuel Consumption

Many plants in the U.S. use incineration for disposal of dewatered sludge. About 25 percent of all municipal wastewater sludge generated is disposed of by this method. Typically, the process consists of thickening the sludge to about 4 percent solids, dewatering with vacuum filters or centrifuges to 15-20 percent solids and incineration in a multiple hearth or fluidized bed furnace.

At the Frank E. Van Lare plant in Rochester, New York, vacuum filter cake at 16 percent solids is incinerated in multiple hearth furnaces. The sludge has a heat value of about 16.2 kJ/kg (7,500 BTU/lb) and requires 1,670 l (200 gallons) of fuel oil per dry ton of dry sludge solids. For the 64 metric tons (70 tons) per day sludge production this amounts to 53,000 l (14,000 gallons) per day at an annual cost of $3,942,000 (at $.90/gallon).

A study of alternate dewatering methods resulted in the replacement of the vacuum filters with continuous belt presses capable of obtaining 25 percent solids. Based on the average throughput of 64 metric tons 70 tons) per day of dry sludge solids, the daily fuel oil consumption was reduced by over 50 percent to 21,196 l (5,600 gallons) resulting in an annual savings of $2,102,400. The installed cost of the belt presses was $1,200,000. As an added benefit the six presses use 130,000 kWh less per month than the vacuum filters; an additional annual savings of $62,400.

TABLE 4 - Effect of Moisture Reduction on Sludge Incineration at Frank E. Van Lare Plant in Rochester, New York

Dewatering Device	Vacuum Filter	Belt Press
Moisture Content (%)	84	75
Throughput (metric tons/day)	64	64
Auxiliary Fuel (liters/day)	53,000	21,200
Annual Cost of Auxiliary Fuel ($)	$3,942,000	$1,840,000
Annual Savings ($)		$2,102,000

Summary

Use of high solids dewatering devices, high efficiency motors, demand control and energy efficient equipment is equally applicable to new installations. I have presented some examples in the discussion on conservation at existing facilities, purposely. In new plant construction we generally plan over a 20 year amortization period and can consider many other techniques. All of the items discussed above can be implemented at existing facilities.

We have just started to go back to the plants we constructed in the '60s and '70s to retrofit them to minimize energy consumption.* With so many treatment plants constructed over the last 15 years maximizing energy efficiency at existing plants offers an enormous potential for energy reduction.

INNOVATIVE TECHNOLOGY

New treatment plants are being designed to maximize energy efficiency. Today's plants include such innovative technology as passive and active solar heating, effluent heat pumps, heat wheels, incinerator waste heat recovery, electric turbines on plant effluent, co-disposal of refuse and sludge to produce electric power and use of digester gas for electric generation.

Heat Pumps

The Cleveland, Ohio, Southerly Wastewater Treatment Plant expansion (525.7 m^3/s, 200 mgd) will use effluent water-to-water heat pumps to provide heat for 13 buildings. The heat pumps are expected to save 1,000,000 l (265,000 gallons) of fuel oil annually. The heat pump is a reversible-cycle refrigeration system that provides heating and cooling. Heat pumps are a standard item, however, that have not previously been applied to wastewater effluent. In the winter, wastewater is considerably warmer than ambient air and can supply enough heat to satisfy building heating requirements. At the Southerly plant 10 heat pumps ranging in size from 820,000 BTU/hr to 4,210,000 BTU/hr will be used. Treated effluent is supplied to the evaporator section of each heat pump as shown in Figure 5. The treated effluent raises the temperature of the refrigerant, which in turn heats the water in the building's heating system.

Energy Wheels

Like heat pumps, energy wheels are commonly used in other industries to cut heat losses from building exhaust air. The energy wheel is a rotary air-to-air heat exchanger consisting of a revolving cylinder packed with a coarse knit metal mesh as shown in Figure 6. The packed cylinder rotates through the exhaust air stream and picks up heat. The contaminated air is purged and the cylinder continues to rotate through the outside air stream, transferring heat to the incoming cold air streams. The system at Cleveland used 21°C (70°F) exhaust air to preheat outside air from-18°C (0°F) to 13°C (56°F). The energy savings is 60,000 BTU/hr or 1.89 l (0.5 gallons) of oil per hour per 472 l/s (1,000 cfm). The six units at Southerly are designed to extract heat from a total of 89,700 l/s (190,000 cfm) of exhaust air, saving an estimated 352,000 l (93,000 gallons) of oil annually.

Solar Heat

The Wilton, Maine, plant (1.2 m^3/s, 0.45 mgd) was the first plant in the United States to be built with extensive use of solar heating. The plant has been operating since 1978. Other plants using solar heating are Skaneateles, New York; Shelburne, Vermont; and Kelseytown, Connecticut.

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*In 1977 there were 13,220 secondary and treatment plants in the U.S.

Solar energy at Wilton uses both passive and active solar technology. Dark brick masonry walls allow the outer skin of the building to adsorb heat. Translucent fiberglass (90 m^2, 960 square feet) panels with insulated passive solar collectors are oriented at a 60 degree tilt to introduce heat into the process area and onto darkly painted walls. Similar panels are used on the bio-disk building.

In addition, the plant contains 130 m^2 (1,400 square feet) of flat plate active solar panel set at 60° from the south roof of the treatment plant. The collectors consist of extruded aluminum plate and frame, copper tubing to transport the water-glycol collector fluid, and two panes of low iron tempered glass covering. The gylcol is heated to a temperature between 50°C (122°F) and 60°C (140°F) by the sun to provide hot water heating for the digesters.

Waste Heat Recovery

At the Frank E. Van Lare Water Pollution Control Plant in Rochester, New York, belt presses have been installed to reduce incinerator fuel consumption. Future plans involve the conversion of the furnaces to the starved air combustion mode of operation. Starved air combustion will further reduce fuel oil consumption by 13,250 l/d (3,500 gallons per day) ($1,150,000 per year). This conversion has a pay back of 2 years.

Starved air combustion of sludge in a multiple hearth furnace, shown on Figure 7, is accomplished by admitting an amount of air to the furnace less than the theoretical amount necessary to burn the sludge. Fixed carbon at the bottom of the furnace is burned to produce carbon monoxide and heat. The heat released is used to destructively distill the volatile organic fraction from the sludge and evaporate water. The resulting pyrolytic gases leaving the furnace are combusted in an external afterburner. Sensible heat from the afterburner exhaust stream may be recovered as steam in a waste heat boiler. This steam may be used in sludge heat conditioning units, for plant heating, or may be expanded within a steam turbine generator to produce electricity.

The primary advantage of the starved air combustion mode is reduction on overall excess air rates. Excess air can be reduced because heat release within the furnace is decreased. The amount of excess air required in the starved air mode is usually less than 30 percent of theoretical quantities, while conventional incineration of primary and waste activated sludge mixtures requires upwards of 100 percent excess air. The lower excess air rate permits autogenous combustion of sludge. Combustion of the pyrolytic gases in the afterburner attains deodorizing exhaust temperatures. The higher exhaust temperatures permit more efficient recovery of sensible heat in waste heat recovery units.

Increased hearth loading rates are also possible in the starved air combustion mode, since the heat release in the furnace is reduced. In addition, it has been found that operation in the starved air combustion mode is easier to control than conventional incineration.

Finally, 154 metric tons (170 tons) per day refused derived fuel (processed refuse) will be added to the furnaces to completely eliminate the need for auxiliary fuel oil. Waste heat from the afterburner will be recovered in a heat recovery boiler to produce steam. The steam at 400°C (750°F) and 4.2×10^5 kg/m^2 (600 psi) will be expanded in a steam turbine generator to produce enough electricity to power the entire wastewater treatment plant (6,000 kW). At that time the treatment plant will be totally energy independent except for heating requirements. Figure 8 shows a schematic of the proposed facility.

By-Product Fuel Use

The 97 m^3/s (37 mgd) Clark Company, Nevada, treatment plant will use digester gas to drive diesel generator sets with waste heat recovery in a combined cycle. Rejected engine jacket water and exhaust gas heat will be recovered in a closed circuit hot water system and used for digester heating. A high pressure gas storage tank will stabilize gas fuel supply. Gas produced during high production is stored for use during low production. A total of 930 kW continuously produced by the two generator sets will be used in-plant to offset utility power requirements. Figure 9 shows an energy balance for the facility.

The use of gas driven engines in the utilization of waste gas is preferable because of the losses in converting it to electrical power. Where digester gas is utilized for powering equipment, gas storage facilities can provide for demand fluctuations.

Sludge Disposal

Sludge processing and disposal represents approximately 50 percent of treatment costs and energy use. Implementation of low energy sludge processing systems has received renewed attention. These include composting and land application.

The static pile composting method was recently developed at Beltsville, Maryland, and is being used at Washington, D.C.; Bangor, Maine; Camden, New Jersey; and Durham, New Hampshire.

At Beltsville, raw, vacuum-filtered sludge at 20 percent solids is mixed with wood chips in the ratio two parts wood chips to one part sludge. The mixture is piled 2-2.6 m (6-8 feet) high over a 0.3 m (12-inch) layer of wood chips containing a pipe network for aeration. A 0.3 m (12-inch) layer of cured compost is placed over the mixture to provide insulation and to prevent odors from escaping into the atmosphere. Air is drawn through the pile at 140 l/s per m^2(500 cubic feet/hour/cubic foot) of compost.

The air is deoderized by discharging it through a small pile of cured compost where temperatures reach 50°C or higher. The mixture is composted for about three weeks and removed to a storage pile for curing and drying. The material is then screened to reclaim the wood chips and for distribution of the compost. The compost from Beltsville is used by public agencies for lawns, parks, and highways. It is a suitable soil conditioner, having nitrogen and phosphorus contents of about 0.8 percent, a moisture content of about 40 percent.

and excellent moisture retention. Figure 10 illustrates the static pile composting method.

The Bangor operation also utilizes raw vacuum-filtered sludge that has been treated with lime and has a cake solids content of 20 percent. Bark wastes are used as the bulking agent in the ratio three parts bark waste to one part sludge. The volume of a compost pile is about 150 m^3 (200 cubic yards). The composting process requires three weeks, provided that the temperature in the center of the pile is maintained at 55°C for at lease two days.

Another low energy sludge processing system which has received much recent attention is the Carver-Greenfield Drying system. The Carver-Greenfield process is a method of removing water from partially dewatered sludge using the principal of multiple effect evaporation. The system uses a light weight oil as a carrying fluid for the sludge, thereby avoiding problems of thickening, scaling and fouling that would be encountered in normal evaporation. Figure 11 is a simplified schematic of the process. Sludge is fed into a unit at anywhere between 0.5 and 40 percent solids and mixed with fluidizing oil. The sludge/oil mixture is pumped to a multiple effect evaporator in which most of the water is evaporated. The product is then centrifuged where the oil and sludge are separated. Further recovery of fluidizing oil is possible by hydroextraction whereby residual oil is steam stripped from the sludge. The dryed product is pathogen-free and may be sold as a soil conditioner or burned to produce steam and electricity.

At 20 percent solids feed surplus power can be generated (beyond process requirements). For example, a unit processing 91 metric tons (100 tons) per day of sludge dry solids can produce net power of 2,250 kW. This process is planned for use at the Los Angeles, California City, plant and the the Ewing-Lawrence plant in New Jersey.

CONCLUSION

These are just a few of the technologies being used today to combat high energy costs and reduce consumption. Many other examples could have been cited if time permitted. It is important to remember that as the relative price of energy increases, concepts that appeared economically unfeasible just a few years ago may not be so tomorrow. We must constantly reassess our thinking in light of the constantly changing costs.

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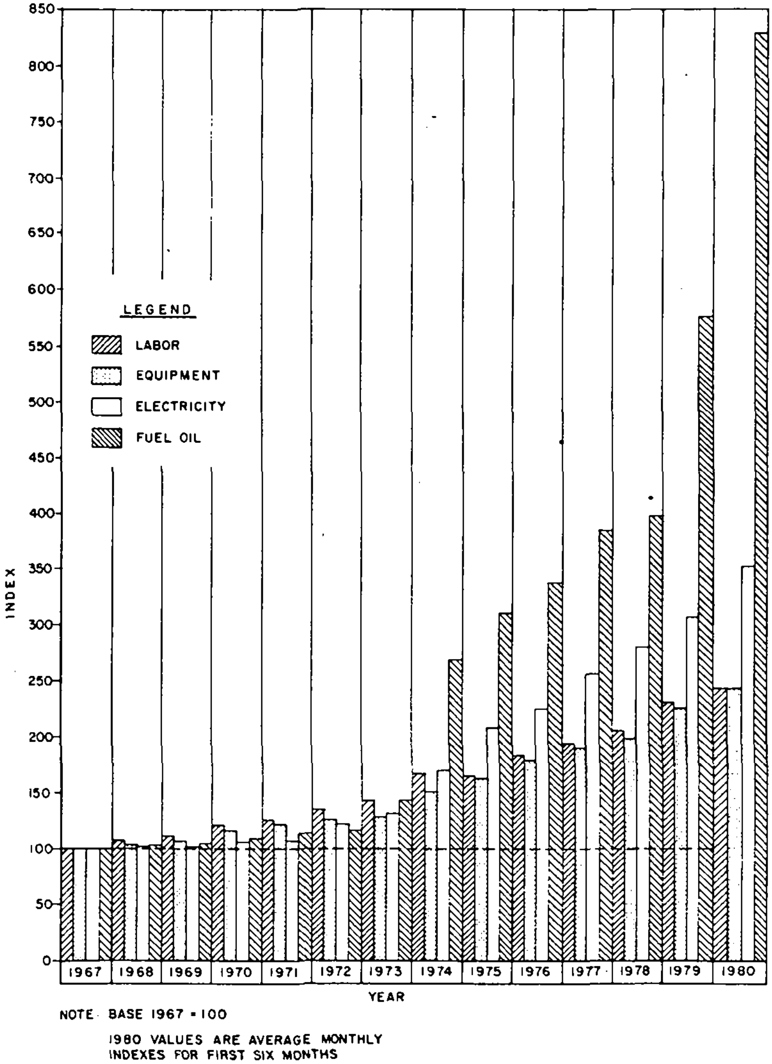
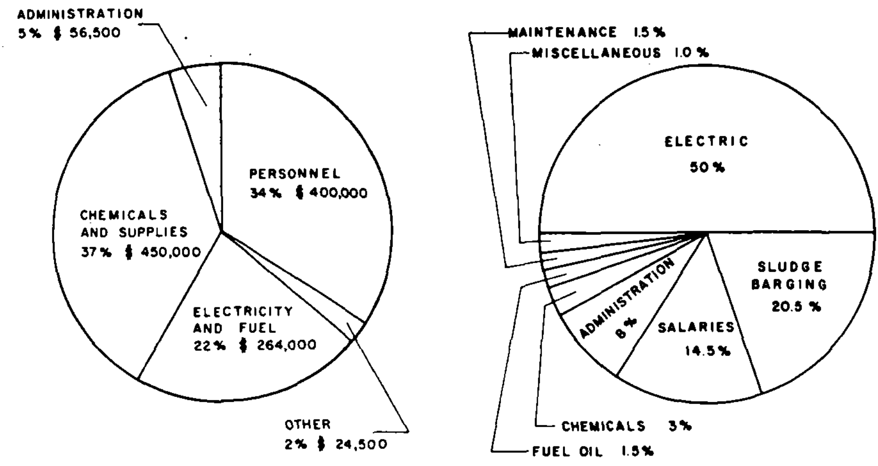


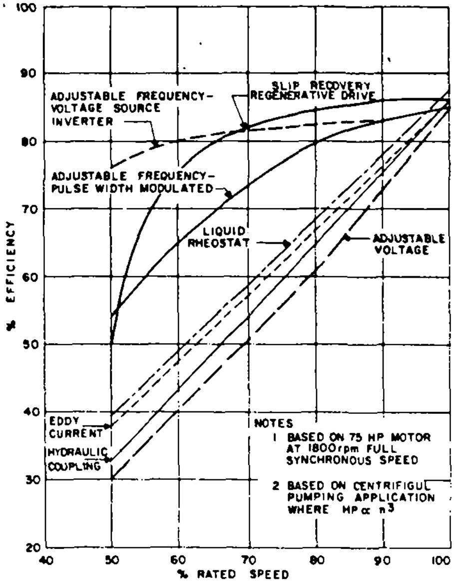
Figure 1 Relative prices of labor equipment, electricity and fuel oil



1980 BUDGET FOR JERSEY CITY WATER FILTRATION PLANT

MIDDLESEX COUNTY UTILITIES AUTHORITY 1980 BUDGET FOR CENTRAL TREATMENT PLANT OPERATIONS

Figure 2 Typical treatment works budget



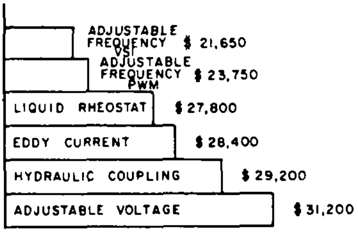
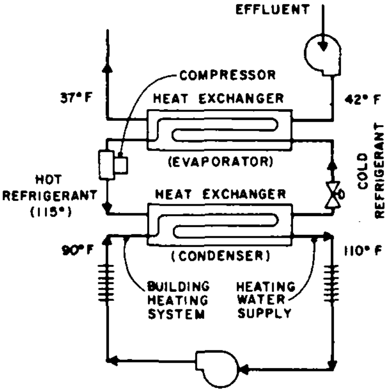


Figure 3 Efficiency comparison of variable speed drives

Figure 4 Annual power cost of various 75 HP drives



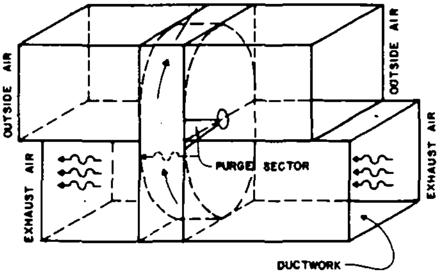


Figure 5 Typical heating cycle for heat pump

Figure 6 Heat wheel

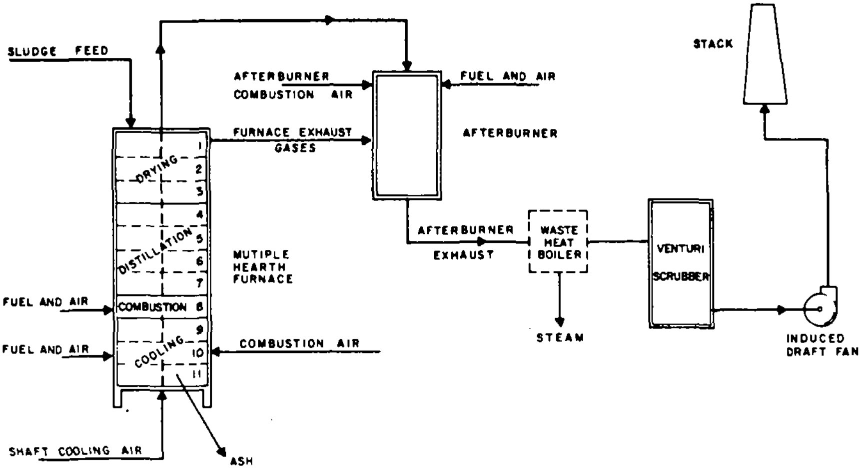


Figure 7 Starved air combustion modification

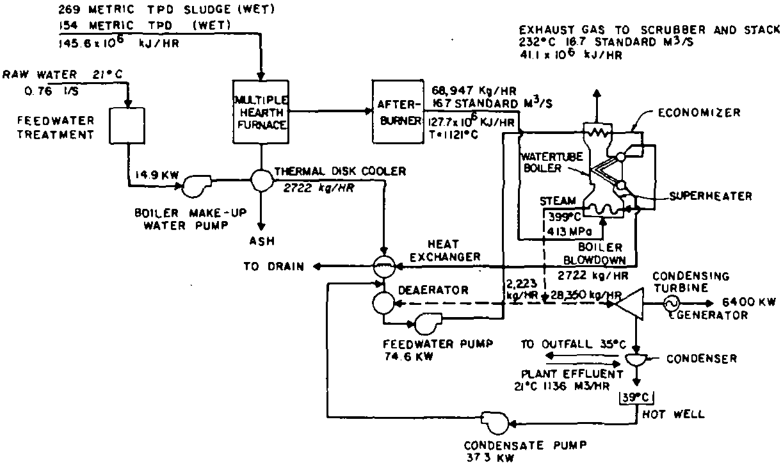


Figure 8 Waste heat recovery schematic
Frank E. VanLare Plant

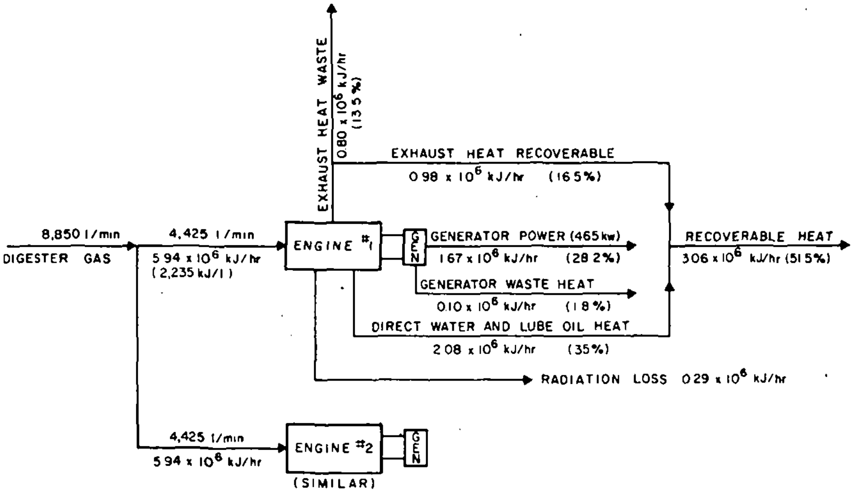
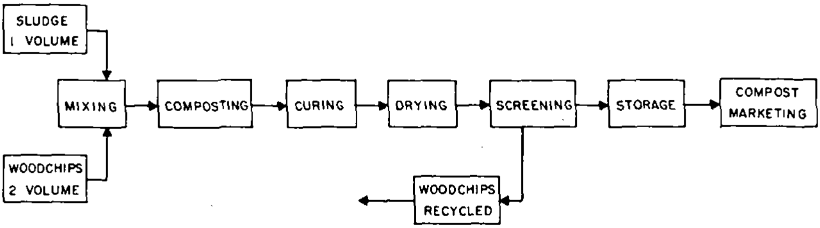


Figure 9 Clark County, Nevada digester
gas energy recovery system



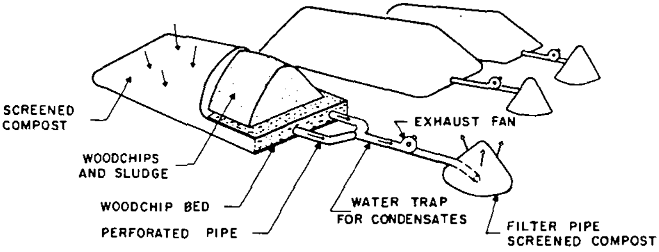


Figure 10 Static pile composting

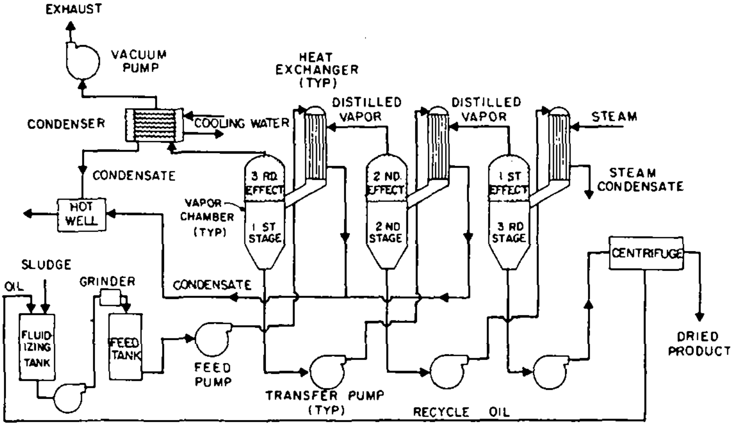


Figure 11 Typical Carver-Greenfield drying process schematic

DISCUSSION

Author's introduction

Mr Jacobs introduced his paper by saying that in the USA, the 1960s was the era of the Great Society: many social programs were introduced by the Kennedy and Johnson administrations. The 1970s was the decade of the environment and saw passage of the Clean Air Act, Water Pollution Control Act, Marine Protection Research and Sanctuaries' Act, Resource Conservation and Recovery Act, and the Toxic Substances Control Act. In the 1980s the major issue was going to be the energy crisis. They had already seen passage of the National Energy Act and creation of the Department of Energy.

In 1978 there were 14,800 wastewater treatment plants in the United States. This number was expected to increase to 20,800 by the year 2000. These plants were generally the largest single energy consumer in the municipal budget. Energy costs were also responsible for the largest operating cost expenditure in the budget of water and wastewater operations, exceeding costs for personnel in recent years.

The aim of his paper had been to show some ways in which energy consumption and costs could be reduced.

Verbal discussion

D.L. WALKER (National Water Council) commented on the dramatic increase in oil prices shown in Fig.1 (page 6.11) and questioned whether the late 1960s provided a representative base line. The figure showed the cost of oil increasing eightfold between 1970 and 1980 compared with a doubling of labour costs in the United States. In the United Kingdom imported oil went up twelve fold compared with a fourfold increase in average weekly earnings over ten years. However, if 1950 was used as the base line, the comparison looked very different. Between 1950 and 1970 the cost of imported oil was stable whereas average weekly earnings increased fourfold. So over the thirty-year period between 1950 and 1980 the cost of imported oil had in fact increased less than average weekly earnings. He suggested that when people referred nostalgically to the era of cheap energy, they should bear in mind that the 1960s were not typical. They were a momentary aberration in the human struggle to use costly energy more efficiently.

He went on to consider the economic criteria for energy conservation, and supported Mr Jacobs' emphasis on the financial savings that resulted from energy savings achieved by good housekeeping and relevant technology. Mr Walker supported previous speakers who had pointed out that energy was not the only scarce resource. To quote a former Secretary of State for Energy, Eric Varley, economic appraisal was necessary to weigh resources of many different kinds in the same scales. That also involved judging the value of future energy savings. Now that the prescribed discount rate was 5% in real terms and the experts were predicting increases of at least 2% per annum in energy costs, energy saving investment was much easier to justify than a few years ago. A financial appraisal assuming 15% interest rates and energy costs increasing at least 12% per annum in money terms would give much the same answer.

He concluded by emphasizing the need for energy appraisal in relation to policies as well as projects. Minimizing energy consumption for sewage treatment and sludge disposal might be irrelevant if a properly designed sea outfall had less effect on the environment as well as using less energy. He asked Mr Jacobs not to assume that more treatment and more waste treatment were inevitable in the United States. As some bottles of cough medicine contained more chloroform than a life-times water consumption, was it necessary to use energy on water treatment to reduce chloroform concentrations? To take another example, while the United Kingdom was debating reductions in the effective volume of 2 gallon lavatory cisterns, the United States often seemed to use 5 gallons. Surely this provided scope for energy saving?

W.M. CORMIE (Crouch & Hogg) congratulated Mr Jacobs on the diversity and quality of the contents of the paper and noted with interest the valuable savings of energy and cash which can be achieved by using modern variable frequency AC drive motors and controls.

The high cost of sludge treatment was a considerable problem and Mr Haseldine had previously spoken about long sea outfalls. In Scotland sludge had been discharged from boats into deep waters round the coast and this too had proved to be economical and acceptable. It seemed unfortunate that US laws did not permit this method of sludge disposal in coastal areas.

The ingenious ways of harnessing and conserving heat as set out in the paper were extremely interesting and developments in these fields which had not so far been used in this country should be watched closely.

Throughout the paper the overall cheapness of the schemes was clearly paramount, and no doubt cheapness also reflected, in most cases, energy efficiency. But there were many cases where this might not be the case.

For example, Mr Cormie's firm was responsible for one of the larger water schemes in Scotland which required pumping all the water from a little above sea level. The scheme was set out using different level zones of supply to achieve maximum pumping economy. The public inquiry into this project was held in 1965. At that time the low capital cost of the project attracted their clients and with electricity costs rising at only 2½% per annum the scheme was accepted. Electric power costs were now some five times greater than in those days while the pound had been very greatly devalued and energy was a scarcer commodity. Would it have been right to have chosen a very much more costly scheme based on upland sources thus saving energy in the long term and writing off the high capital cost with devalued pounds? Financially what was done at that time was absolutely correct and all the economists agreed. Our successors might take a different view.

Referring specifically to the paper, Mr Cormie said that there was a remarkable difference between the Frank E. Van Lare plant in New York where 64 t of sludge required 14,000 gal of oil per day for incineration and the proposed Carver Greenfield drying system for Los Angeles where a net production of over 2000 kW per day was expected.

Finally, he commented on the statement on page 6.2, that waste water and water treatment and water distribution accounted for 2½% of the total energy used in USA and 8% of the total electric consumption. These figures were quite remarkable and clearly must make every engineer realise the absolute necessity for introducing and maintaining every feasible economy.

R.A. PEPPER (Sunderland and South Shields Water Co.) said that three themes in Mr Jacobs' paper were of considerable importance to the water industry: the development of unconventional energy sources; the management of the use of plant to minimize charges, and the proper selection and use of high efficiency equipment to reduce total energy consumption. Those in the clean water side of the industry were conscious that they were not able to make the same contribution towards the development of unconventional energy sources as were those concerned with sewage treatment. They should, however, endeavour to exploit the less conventional forms of energy wherever appropriate, including, for example, wind power. There were also other energy sources which should always be reconsidered when economic factors changed the balance of decision making.

Mr Jacobs was to be congratulated on his courage in drawing attention to the sad tale of the Schenactady pumping station, but who could be absolutely sure that a similar if less dramatic situation was not occurring within his own undertaking? However, Mr Pepper was concerned that although minimizing energy charges was highly desirable, it was unlikely to save much energy. It was a management task to ensure that any given tariff structure was used effectively, but if all users so arranged their affairs that they were able to reduce charges without at the same time reducing the total consumption of energy then the energy-producing industry would merely have to restructure its tariffs. This aspect was always important in proper management, and required that previously suitable philosophies and operational activities be re-appraised, but was not, in Mr Pepper's view, fundamental.

The most important theme was the essential need to develop the use of high efficiency plant and equipment capable of meeting a desired end objective at minimum energy consumption, and to operate it in the most efficient way. The industry must take note of the philosophy behind Mr Jacobs's term 'retrofit', and accept a continuing need to respond to changes in the objective and to reconsider the equipment provided and mode of operation.

Mr Pepper invited the water industry to widen this philosophy and to reappraise not only the objectives expected from any scheme but also the whole concept of some proposals. The energy element inherent in some bulk transfer and river regulation schemes was substantial and the increasing implications not only of cost but of future availability of energy must come into the decision processes. It would be helpful to derive more far-reaching 'energy audits' not only from the water industry's point of view but also from that of the whole community. Was enough research being done in this field generally? The answer was far from clear but circumstantial evidence suggested that the industry must move towards the adoption of low energy schemes even though these might incur higher initial capital costs in some instances.

R.W. BAYLEY (Water Research Centre) asked Mr Jacobs if he could give more information on the Carver-Greenfield Process? From what had been said it seemed possible to operate one of these plants and produce energy in excess of site requirements. Could this be supported with substantiated observations? In particular, Mr Bayley enquired into the separation of sludge from oil. Was there not a serious likelihood of ending up with oil containing too much sludge and/or sludge containing too much oil?

Author's reply to discussion

Mr Jacobs, in reply to Mr Walker, said that it was true that during the 50s and 60s the cost of oil and electricity had remained relatively stable while labour costs had increased significantly. However, the important point was not what had happened in the past, but what the relationship was today among the competing costs which contributed to the overall operating budget. The real point was that capital investment to reduce energy costs and consumption, which had not been economically justified or available when the facilities were constructed, was now worthwhile.

It must be emphasized that the majority of secondary and advanced wastewater treatments, which were major uses of energy, were designed and built in the late 60s and 70s and that the decision making process was based on the relative cost of labour, equipment, and energy prevailing at that time. It should also be noted that technological improvements had only recently resulted in the availability of certain high efficiency equipment.

Energy management decisions must be based upon the best available present-day predictions. Although it was unclear what the future might bring, he believed it was safe to say that energy costs would continue to increase at greater rates than labour and capital costs for the foreseeable future (the next 10 years). Given this fact one must escalate energy costs at greater rates than labour, capital and chemical costs. This type of analysis would show clearly the merits of making capital investments today to save energy costs in the future and would also point out the sensitivity of different alternatives to changing future cost and availability relationships.

Decisions relative to improved water quality or greater degrees of sewage treatment must be made in consideration of economic and environmental trade-offs. Any such decisions must also consider the acceptable level of risk set against the cost to reduce that risk level. Obviously if one bottle of cough medicine was equivalent in chloroform intake to a lifetime's consumption of water, one could not justify great expenditure to further reduce chloroform contents of public water supplies.

The question of sludge disposal at sea was far more complicated since the degree of risk was much more difficult to measure. The relative risk of ocean disposal and alternative impacts on air and land had not been assessed completely and probably never would be. The debate on ocean disposal of sludge in the US was far from over. However, decisions (even political ones) could only be made on the basis of the facts available at the time. When wastes were dumped in 'Love Canal' decades ago this too was considered safe. Time proved that it was not. Even though the decision to discontinue ocean disposal did not appear to be justified on the basis of what was known today, only the future would show whether it was the right decision or not.

In response to comments made by Mr Cormie, Mr Jacobs said that only monetary savings were a true measure of assessing energy savings. If the economic analysis was properly performed, it would reflect increased costs of energy resulting from supply limitations. Proper analysis required a projection of conditions prevailing over the life of the project and must consider increased future cost of scarce resources. Mr Cormie used an example of sea level pumping requiring lower initial cost but higher energy consumption v, use of an upland source requiring higher capital but reduced energy consumption. In the 1965 analysis it appeared that the pumping scheme had the lowest project cost and was selected. However, based on present-day economics perhaps the upland gravity scheme was actually less expensive.

The problem here was that the economic criteria used to evaluate the project was incorrect. The 'crystal ball' used in 1965 gave a distorted picture of relative costs over the project life. Had the crystal ball been accurate, future energy costs would have been accurately projected and a different scheme selected. This did not change that fact that the choice had to be made on the basis of economics as they were foreseeable at the time.

He then commented on the conventional incineration process used at the Frank E. Van Lare plant and the Carver-Greenfield process which resulted in a net production of energy. When the Frank E. Van Lare plant was designed the engineers did not envision consumption of 14,000 gpd of fuel oil. Two factors accounted for this increased consumption: the sludge cake from the vacuum filters averaged only 14% solids rather than the 18% that had been expected; and the temperature of the exhaust gas had to be increased from 800°F to 1400°F to control odours. The owner had initiated studies to reduce oil use. Presently oil use was about 5000 gal/day resulting from replacement of the vacuum filters with belt presses capable of obtaining 25% solids.

It should also be noted that additional modifications were being implemented that would eventually result in the use of the waste heat to produce electricity. On the other hand, the Carver-Greenfield process was being designed with energy recovery in mind. This process was also relatively new and was not available for use in processing wastewater treatment plant sludges until recently.

In reference to one of Mr Pepper's comments, Mr Jacobs said that he believed that reducing energy charges was synonymous with reduction of energy. Although improving power factor charges or demand charges did not necessarily reduce energy consumption at a particularly facility, if one looked at the basis of these charges the energy savings became obvious. Power factor charges reflected the efficiency of use of energy. The power company had to generate more power to supply facilities with low power factor than facilities with high power factor. This was why they penalized customers with low power factors.

In terms of demand charges, the power company demand charges were based on the cost of operating equipment necessary to meet peak demand. Power utilities operated the equipment with which they could generate the lowest cost power first (hydroelectric or nuclear). As system demand increased they had to bring the higher electric cost facilities on line to meet their system wide peak demand. For example, peaking power may be provided by gas turbines which had the highest cents per kWh operating cost.

If peak demands were lowered the electric company's 'high cost' facilities would be used less frequently resulting in less consumption of scarce fuels (natural gas and oil). If peak demands were reduced (even if energy use was not) less high-cost fuels would be used, being replaced by use of abundant low-cost fuels (nuclear and coal). This was energy reduction as well as cost reduction.

Mr Bayley had raised a number of questions regarding the Carver-Greenfield Process. Time and space precluded answering his questions within this text, but they were answered in a report which described the Carver-Greenfield Process in detail*

* 'The Carver-Greenfield process state-of-the-art for municipal sludge management - an evaluation' Metcalfe & Eddy, New York, July 1979

SUMMING UP THE SYMPOSIUM

Summing up the symposium, J.G. LLOYD (Chief Executive, North West Water Authority) said that it had been a truly important and topical occasion. He quoted the first sentence of the notice for the meeting, in order to set the scene. 'Save Energy is a topical catch phrase of our age, and seldom does a day pass without some reference to the energy crisis'. The notice went on to imply that the meeting was called to talk about saving energy, regarding the consequential saving of money as a valuable by-product.

Members would be very pleased that the Minister had been able to attend at the beginning, to deliver his enthusiastic and stimulating address. Although he had been unable to stay throughout the proceedings, he had left an observer who would be able to take back messages arising out of the discussion, so Mr Lloyd would pick out one or two for his consideration.

The business of the water services could be regarded as founded upon *the interaction of people, professionals, and politicians.* Dealing first with the professionals and their contribution to the symposium, he drew attention to the need for clear thinking about energy saving, especially as he thought there had been evidence of some unclear thinking in the papers and the discussion. Two kinds of clear thinking were needed. The first was 'long-term thinking ahead' of the kind provided by Dr Chesters in his paper and oral introduction. Dr Chesters's maps and their themes were most interesting, as were his tables comparing energy demand and resources. Possibly, though, the lesson learned from the now discredited belief that water demand would double by the end of the century would cast doubt on the validity of his forecast of energy demand. He had given the impression in his paper that he thought environmental objections to the development of alternative sources of energy on a large scale could be fairly easily dealt with, but his oral statement showed that he was alert (as water engineers have learned to be) to the scope for difficulties and long delays in that respect. Dr Chesters's contribution was interesting and stimulating, and it was a pity that there could be no discussion of it.

The second type of thinking was concerned with good housekeeping, of the kind so ably described by the authors of the last six papers, notably by Mr Thomas and Mr Wright. All the papers and contributions to the discussion would repay careful study when the transcript became available. He wished, however, to refer expressly to Mr Cash's paper, not just because he agreed with almost all of it but because many of the speakers were understandably uneasy about the paragraph on the relationship between energy and cost at the bottom of page 2(a)7. It was there postulated that optimizing costs would lead to optimizing energy use, with an implication that the reverse was also true. Mr Lloyd did not belive this was correct, except in the very limited sense that Mr Cash had probably intended in his context at that point. Much of the discussion brought this out into relief, and revealed that the statement would be dangerously misleading if quoted out of context. A few examples would make this clear.

Mr Thomas and Mr Wright wrote that money could be saved by checking accounts, but that would save no energy at all. That was an extreme example and the Minister provided a more significant case in his opening address when he referred to leakage of water and the consequential waste of energy. The suppression of leakage was a costly operation, and notoriously labour intensive. While demands for energy saving would certainly call for reconsideration of the economic break-even point, they would not make leakage suppression significantly cheaper or less prodigal of manpower. Again, small scale hydropower installations of the kind to be seen at waterworks may produce ostensibly cheap energy, but Mr Banks had pointed out how difficult it was to sell the power, while the manpower costs of operating these small remote plants were causing some to be phased out under current drives for financial economy.

Mr Rofe had bluntly asked were they in the business of saving energy or saving money? There used to be a little saying amongst members of the Institution, attributable to a Past President, Mr H. R. Lupton, who said 'It pays to pump'. What did that mean? Mr Lloyd believed it meant that when you were working up a scheme to solve a waterworks problem, think carefully about all the alternative solutions, and you would be surprised to find how often the projects with high pumping costs (i.e. high energy usage) turned out to be financially cheaper than the capital intensive projects. Yet, many of the contributors to the discussion in these two days had advocated capital intensive policies in order to save energy, several apparently without careful thought about the consequences for financial cost. This was a complicated scene, as Mr Speed and Mr Pepper had indicated when they spoke about large scale river regulation schemes, and perhaps the best way to make the point was merely to say that the desire to avoid waste of energy resources was a new factor to be taken carefully and fully into account, along with the financial costs of energy and of capital when policies were being formed. It seemed dangerous to try to be more specific than that when stating principles.

Decision-making for the planning of water schemes was, however, not just a matter for the professionals, nor yet for the promoting authorities themselves. He quoted a particularly telling example of his own to make this clear, after emphasizing that he was doing so to make a general point rather than to enter special pleading for that particular case. This was a project for the provision of extra water supplies for the people of a certain district and for the nuclear fuel industry already established there. It had been proposed to create new reservoir storage by raising the level of a very beautiful natural lake, the rise being as little as four feet. The project was the cheapest that could be conceived for the purpose, and was essentially a gravitational scheme with minimal requirements for energy. It was said by objectors that it would cause great and permanent damage to the environment. The alternative put forward as preferable by the objectors was for a river abstraction, involving pumping over a high ridge followed by discharge to a natural watercourse and, several miles further downstream, a second river abstraction. Here was to be seen in stark form the interaction of the topical issues of water demand, financial cost, energy requirements, water quality, and considerations of environmental impact. The water authority had played its part in the policy-forming process, and the actual decision about what was to be done was now to be made by the Minister following a public inquiry. Mr Lloyd expressed his own view of this case, but no more strongly than by saying he hoped the Minister would take into account his own words on the need for energy conservation when settling that and other cases of a like nature. A water authority could not save energy in such a case if prevented by a Ministerial decision.

He went on to the matter of good housekeeping, which had figured so often in the discussion. When weighing existing operational arrangements against the need for better and more economical use of energy, it was almost always found necessary first to spend money, either capital or revenue or both, as a kind of investment. But water authorities were now effectively controlled by Government constraints on their budgets, within which they were obliged to work. There were cash limits (the external financing limits mentioned by the Minister in his address), financial targets, performance aims, together with repeated demands for the reduction of manpower. So, the second message to the Minister that could be distilled from the symposium was 'if you want us to conserve energy, please take that into account when you are setting our constraints. It will only be through the wise setting, as well as the dedicated using, of the constraints that we shall be able to do what you want'. When all was said and done, a water authority's top priority for spending money in times of severe economic stress would be to deal with cases where the services to the public had actually broken down through chronic supply failures, repeated flooding of houses by sewage, interruptions of sewage and traffic flows by sewer collapses and so on, rather than investment in energy saving, unless the Government's constraints allowed or encouraged the latter.

Many good points had been made in the papers and discussion, and he picked out a few. Mr Coates had rightly called for interdisciplinary working. Mr Bensted had referred to solar energy, which already provided all the raw material for the water industry through evaporation and natural desalination. Mr Haseldine emphasized that the use of energy by the water industry was relatively small, but increasing. Mr Martin's ideas for use of stable units of energy in place of money units for comparing alternative projects would hardly find favour with the Minister when talking about capital programmes as a whole, as Mr Walker had implied. Mr Clapham's reference to biogas was important, but much of the rest of his paper was justly criticized by Mr Willis and Dr White. Mr Thomas and Mr Wright were to be congratulated on their efforts to put ideas for good energy housekeeping into practical effect. Their paper would be a useful stimulus to similar efforts elsewhere. Mr Huntington had given inspiring examples of the scope for energy saving through investment in telemetry. Mr Jacobs had produced spectacular examples of fuel saving in the United States through highly sophisticated systems on a large scale. Careful study of his paper would give much food for thought and hope for success in this country if the requisite money could be spared to follow his lead.

One very significant matter had not been mentioned during the proceedings. The water industry was not an energy producer, except on a very small scale. It was an energy user. The energy producers were the National Coal Board, the British Gas Corporation, the oil industry, the nuclear fuel industry, and the electricity generating Boards. These were familiar names to water men because they had so many points of contact in the course of business, in such matters as opencast coal sites, deep mining and its interference with aquifers and surface drainage, the underground storage of gas, oil pipelines through water catchments, cooling water requirements of power stations, and so on. There was very considerable interdependence in cases of pumped storage schemes for fuel saving on the electricity grid such as that at Dinorwic. There are proposals for pumped storage in the Longdendale valley, where three impounding reservoirs supplying the Manchester area would become incorporated in the new lower reservoir. Water authorities, therefore, had great opportunities for helping the energy producers in their important schemes, or for being indifferent or even obstructive albeit for good reasons to protect the interest of their own customers. Should they not strive to be as helpful as possible to the energy producers in the furtherance of their fuel saving schemes in the national interest? Mr Lloyd thought this was one of the major contributions the water industry could and should make towards a national policy for energy conservation.

He concluded by saying that the symposium should be regarded as the beginning of a new burst of energy by the water industry directed towards the proper and economical use of energy; subject, of course, to the wise remarks made in the discussion and to Government policy on expenditure.

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