ENERGY FOR TOMORROW

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Introduction

The events of October 1973 which culminated in the decision of the petroleum producers to increase the price of crude oil by 500%, and in the application of an oil embargo to various countries, have led to a preoccupation with the subject of energy. This preoccupation has taken the form mainly of discussions on the shortage of energy and how best to use energy forms other than the conventional ones of oil and coal.

However, it must be realized that there is presently no shortage of energy, there is only a shortage of cheap oil, and the introduction of new forms of energy must always be viewed as an economic exercise with the new forms of energy being in competition with the established forms.

The largest source of energy used today is fossil fuel, whether it be coal or oil. On a world basis oil has the largest share of the energy market. For instance, oil in 1972 had a 44% share of the world energy market, whilst coal had 32%, natural gas had 21% and the remaining forms - hydro, nuclear, geothermal, etc. - had 3%. This large reliance on oil was caused by oil's cheapness and convenience, especially as a fuel in the transport sector. That oil was cheap can be seen by the fact that the OECD cost index for main products increased by 50% over the period 1961 to 1971 whilst the cost of oil remained constant (Ref. 1). The hike in oil prices towards the end of 1973 was partly a realization of the cheapness of oil as well as a realization that oil reserves were limited and that production would peak in the near future.

When considering energy, the future of energy is considered. This must be done under three headings, short, medium and long term.

In the short term, there is not very much that can be done except to intensify research in selected fields. It is possible to reduce energy imports, as is being done in many parts of the world, by fuel and energy conservation methods. It is possible to modify certain boiler installations from oil to coal or gas but this will be expensive unless the installation has been designed as a dual fuel unit. In general, such modification means a reduction in output capacity. In the medium term the tendency will be to move away from reliance on oil as a fuel and it may be expected that coal and nuclear plants will increase, at the expense of oil, for electrical power generation.

It is difficult to see on the global scale any fuel taking over dramatically from oil in the transport industry. Whilst various transport forms such as battery driven vehicles will make inroads into the internal-combustion engine market, it is doubtful whether this competition will be significant unless there is a dramatic breakthrough in battery technology.

Also in the medium term, one expects to see various forms of gas-from-coal and oil-from-coal plants which will make use of the vast coal reserves of the world.

In the long term it may be expected that nuclear power will play a very large role, with fusion power generation and large scale use of solar

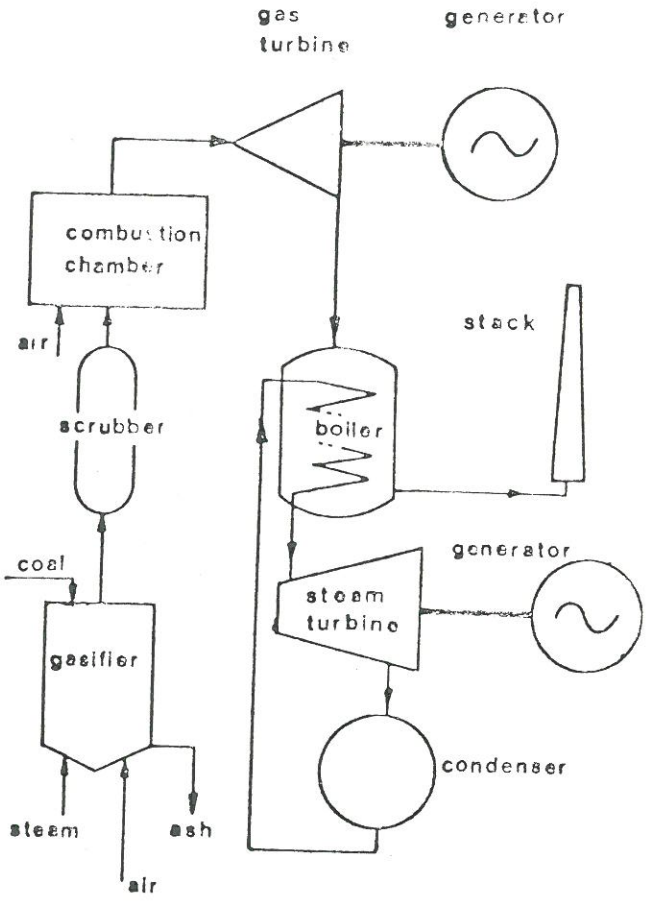

FIGURE 1

DUAL-CYCLE POWER PLANT

power, both exciting possibilities.

Trends in energy production

Trends in energy production indicate that there is a swing away from primary energy sources such as coal and oil, to the secondary energy source electricity. This swing has for instance resulted in an increase of the share of electricity as a percentage of the total energy demand in the United Kingdom from 0,8% in 1920 to 16,3% in 1970. In South Africa the percentages are even higher though the rise is not so dramatic - from around 14% in 1920 to 31% in 1970. This swing has mainly been at the expense of coal and has been caused by the greater convenience in the use of electricity, and by antipollution legislation introduced in many countries of the world. It may thus be of value to consider the medium term future of electricity generation.

The world wide trend in the generation of electricity has, in the past, been toward the installation of larger steam turbines in power stations, with units of well over 1 000 MW now being installed.

However, the rapid increase in the size of these sets has meant that new designs are constantly being introduced without much operating experience having been gained on previous designs.

In this manner weak design features have been carried over into the larger sets and this is shown by the low availabilities attained by the newer units.

The importance of availability to the electricity generating industry is demonstrated by the fact that the United Kingdom's Central Electricity Generating Board now favours the more reliable condensing feed pump turbine to the more efficient back-pressure type.

This emphasis on reliability will result in a slight decrease in the efficiency of power generation. Since the present power station efficiency is anyway approaching a plateau situation, it will mean that no further improvements in efficiency can be expected in conventional power stations and in fact, a slight decrease in efficiency might be expected.

In view of this it is encouraging to note that there are developments in steam power plant which could lead to large increases in efficiency. One of these developments is the dual cycle steam power plant which is a combination of a gas-turbine and steam-turbine. The hot gases from a combustor (see Figure 1) pass through a gas-turbine and then exhaust into a "waste-heat boiler" which produces steam for a conventional steam turbine. This system is expected to increase the efficiency of power stations to 50%. Many such power stations are already in existence and giving excellent service but most of these are fueled by oil or natural gas. However, one notable exception is the Lunen Power Station which produces gas from coal in a gasifier. This station has suffered from many teething problems but there do not appear to be any unsurmountable problems. This station is of particular interest to South Africa with its abundance of low cost coal.

Nuclear power stations, which at present produce a relatively small amount of the world energy are growing in importance. They have, however,

not lived up to the expectations of a cheap, infinite source of energy. Problems encountered have included technical, licensing and financial factors. The financial factor has been particularly severe with nuclear power stations having a cost double that of conventional stations, although with a much lower fuel cost. This has all contributed to the fact that the nuclear power programme is not as advanced as expected.

With the present generation of nuclear reactors the available fuel - uranium - will not last much longer than oil due to the inefficient nature of these reactors. However, the latest developments are in the direction of a new generation of reactors, the "fast-breeder" reactor, which in effect uses uranium fuel 60 times as efficiently as the present reactors. Such reactors have already been built and operated and the expectations are that they will become commercially viable in the middle of the next decade.

The other development of note is the introduction of gas-turbine plant for peaking and emergency stand-by duty. Such units have a high operating cost since they use oil, but also have a very low capital cost, making them suitable for operation at low load factors.

In the field of non-electrical energy, there will be a gradual swing away from oil mainly because of conversion of oil-fired boilers to coal and the fact that most new boilers will be coal-fired. However, oil will remain a significant source of transport fuel until oil-from-coal becomes economically more attractive.

Because of the increasing cost of coal, and pressure from various bodies for coal conservation, there will be an increase in the efficiency of coal utilization. One method which attempts to maximize coal utilization may be the "coalplex" system where coal will be processed in order to extract the various chemicals from the coal, possibly including petrol, and then use the remaining char for electrical power production.

Unconventional energy sources

As an introduction to this section, it would be useful to obtain some perspective as regards the relative importance of some of the unconventional energy sources.

The total solar radiation intercepted by the earth at any one time has a power of $1{,}73 \times 10^{17}$ watts. Of this, only 47% is absorbed by the atmosphere, the land surface and the oceans, the remainder being reflected to outer space or used in evaporation of water, convection currents and precipitation.

Since two-thirds of the earth's surface is covered by water where it might be difficult to set up solar collectors, the useful power available from the sun amounts to $0{,}27 \times 10^{17}$ watts.

The average rate of heat flow from the interior of the earth has been estimated at about 0,063 watt/m^2. For the total land surface area this amounts to about $10{,}6 \times 10^{12}$ watts.

Hot springs and volcanoes have a power of about $0{,}3 \times 10^{12}$ watts and tidal sources could produce about 3×10^{12} watts.

The total power thus obtainable from the above sources would be $21,05 \times 10^{15}$ watts of which solar energy accounts for 99,9%.

Solar energy

The two methods of using solar energy which are receiving most attention are power generation and water heating.

Power generation

Numerous schemes have been proposed to generate power using the energy of the sun.

They all suffer from the same drawback, namely that they are not able to produce power as cheaply as is done at present by conventional means.

Hottel (Ref. 2) has estimated that a 1974 solar plant would produce power for 3,2c/kWh compared to costs varying between 0,7c/kWh in the Eastern Transvaal to 1,2c/kWh in the Western Cape.

For the forseeable future at any rate, solar power generation will not have a significant effect on the world's energy requirements.

Water heating

Solar collectors have been in use for a number of years, especially in households where they are used to assist in heating of water in electric geysers.

Since about 44% of the electricity consumed by the South African domestic sector is used to heat water in geysers (Ref. 3) and since about 20% of the electricity generated in South Africa is used in the domestic sector, about 9% of South Africa's total electricity consumption is accounted for in domestic geysers. If this amount could be halved by the general introduction of solar heaters, this would entail a saving of 2 500 million kWh per annum. About 1,2 million tonnes of coal has to be burned to provide this energy so it can be seen that the saving could be appreciable, although it should be remembered that this amounts to only about 5% of South Africa's electrical energy needs, and 2% of the total energy requirements.

Geothermal power

The earth's temperature increases as one descends from the surface. This heat probably originates from the radio-active decay of such elements as uranium and thorium.

In some regions water may be trapped and stored at temperatures of up to 300°C.

In certain parts of the world this water reaches the earth's surface through geysers, but more commonly, drilling is required. Hot water used for district heating and steam used for power generation can be obtained from these sources. The impurities contained in the steam can cause problems but this source of energy has been tapped in such countries as Australia, Iceland, Italy, Japan, Mexico, New Zealand and the U.S.A.

However, it is likely to remain a very small contributor to the world's energy requirements.

Tidal power

The highest tidal changes in the world (11 metres) occur at the Bay of Fundy in Canada. It has been proposed that a 2 000 MW tidal power plant be built in the Bay but so far, without success.

The only tidal scheme in operation at the moment is at La Rance in France, where a 240 MW station generates power at a cost two or three times greater than that at conventional thermal stations.

Wave energy

It has been proposed that the energy of ocean waves be used to generate electricity. A recent study (Ref. 4) suggests that 1 400 km of coastline along the United Kingdom could sustain 30 000 MW. The costs of installing such a power plant would however be astronomical and the use of this energy form is not expected to occur in the forseeable future. It is estimated that the cost of energy from this project would be double that from conventional power stations.

Wind energy

Although windmills have been used for centuries to generate power on a small scale for pumping water and grinding corn, it will not be economic to erect power units until some cheap method can be developed to store the electricity generated.

Ocean thermal gradients

The idea of using the temperature gradients in the oceans to produce energy is not new and was suggested as far back as 1881.

The idea is that the warm water at the surface of the ocean is used to vapourize a fluid which would then be expanded through a turbine and condensed by the colder water from the ocean depths. Theoretically, the amount of electricity which could be generated in this way is greater than the present world consumption but problems with the installation of the plant, transmission of the electricity and the capital cost of the plant seem to make this form of energy generation unattractive at the present time.

Energy and the environment

The energy industry has for a long time been one of the worst environmental polluters. Although in total emission the domestic sector ranks far behind electric power stations (see Table 1) it emits air pollutants (especially from open coal fires) at roof top levels into urban areas.

Table 1: Emissions - 10^3 tons per year

	Sulphur Dioxide	Dust
Power stations	819	669
Refineries	0	0,2
Domestic	102	14

A second serious source of pollution is the internal combustion engine, especially in the motor vehicle.

Finally, refineries, power stations and industrial boiler installations are large producers of air and water pollutants. Steps have been taken over the years to decrease this pollution. For large power stations grit and dust emissions have been reduced by means of firstly, mechanical collectors having efficiencies around 80%, and more recently by electrostatic precipitators with efficiencies of over 90%. The emission of smoke, especially from small industrial installations is usually controlled by legislation, such as the various "Clean Air Acts", and effected by efficient combustion methods. Sulphur dioxide emissions are increasing in direct proportion to energy production but because of its emission in chimneys with ever increasing heights, the ground level concentrations are not increasing significantly and in fact in countries such as the United Kingdom the ground level concentrations are decreasing in spite of the increase in total emissions. This decrease has been caused mainly by the domestic sector switching from coal to clean energy sources such as gas or electricity.

The trends in energy production described in the previous sectors will have a beneficial effect on pollution levels. At present, in spite of many reports to the contrary, there is no economically viable method for sulphur dioxide removal from flue gases. However, with the dual-cycle system and the coalplex process described previously, it will be relatively easy to remove the sulphur from the gas since it occurs as hydrogen sulphide and not as the oxide. In these systems the removal of grit and dust is an integral part of the process and thus air pollution from these two sources will be reduced.

Insofar as the general trend will eventually be away from coal and to nuclear energy, air pollution by sulphur dioxide, nitrogen oxides, and dust will decrease but at the expense of the ever increasing levels of radio-activity. The legislation affecting the release of radio-activity is already in force and the maximum permissible levels are such that there should not be any health hazard in the forseeable future. The main source of pollution is the possibility of a catastrophic failure of a reactor which would have a very serious effect on the surrounding population.

The use of solar energy will also decrease the pollution levels since solar energy is one of the few non-polluting energy sources. Unfortunately, as described previously, without some break-through in the technology of power generation, solar energy will be used mainly for water and space heating and as such will not account for more than a few percent of the total energy requirements.

The other forms of energy production mentioned are all clean or relatively clean forms of energy and thus any move away from coal and oil towards such energy sources can only be beneficial to the environment.

Conclusion

Because of the increase in the price of oil and the realization that oil is a resource which is fast being depleted, there will be a world wide swing from oil to, in the first place, coal both for power generation

in central power stations, and for the production of oil for transport purposes. Developments in the clean use of coal will however result in decreasing emission levels of pollution from power stations and other coal users.

Nuclear power will gradually replace coal as an energy source with a resulting decrease in air pollution levels although with an increasing risk of a serious radio-active release during a reactor accident. Uranium, the nuclear fuel will however remain a scarce commodity until the fastbreeder reactor becomes commercially viable and increases significantly the efficiency of nuclear fuel utilization.

At present solar energy is not considered a good prospect for power generation but will become a significant source of energy for water and space heating.

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