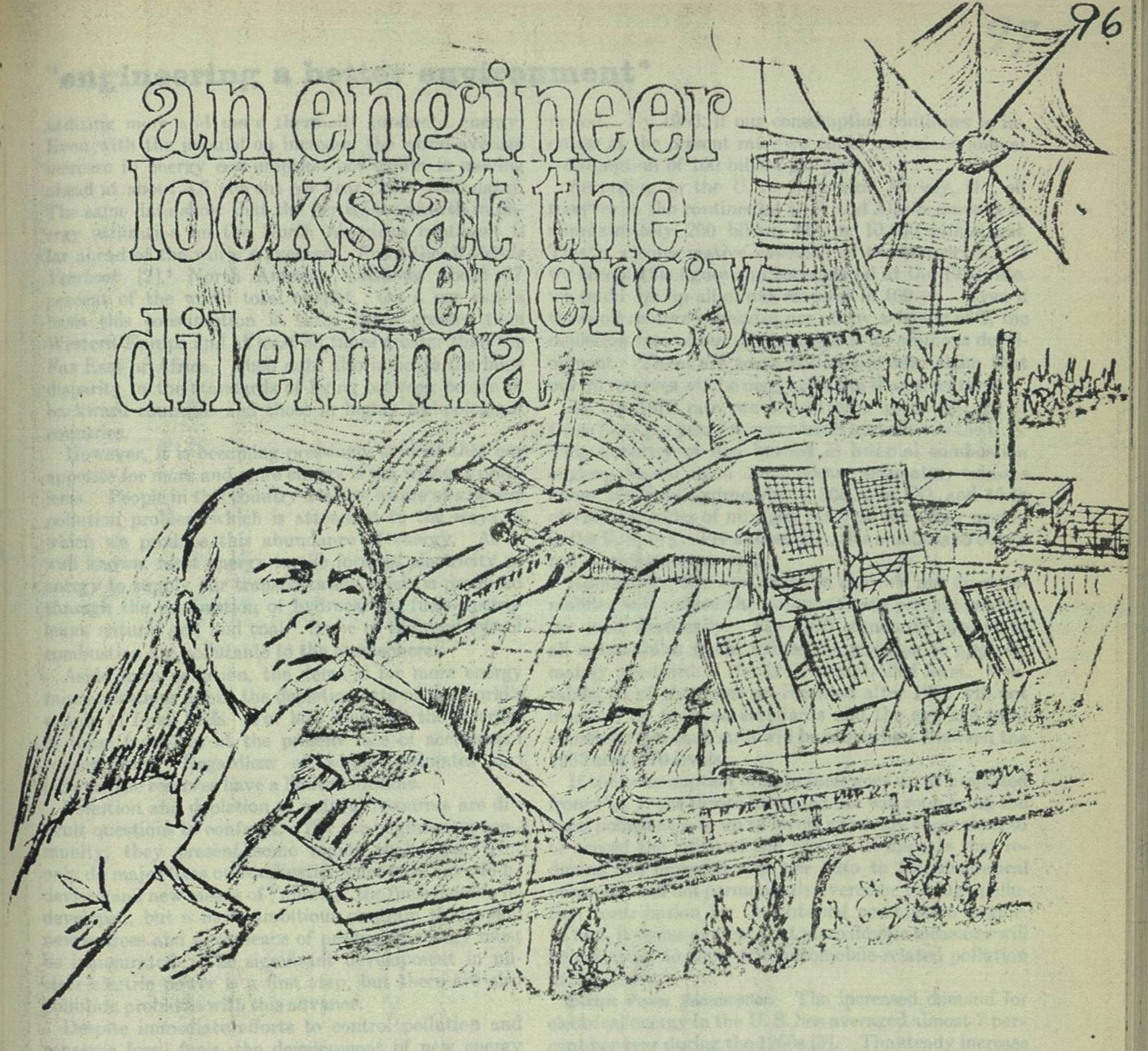
an engineer looks at the energy dilemma



The demand for energy is growing at such an accelerated rate that the attendant problems of pollution and fossil fuel supply depletion point to an urgent need for revision of engineering priorities before making critical decisions for the future. Development of nuclear power, more pollution-free sources of energy, and new concepts of transportation are challenges for today's engineers.

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THE ESCALATING consumption of energy by the world population is a topic currently receiving widespread attention in the news media. Technical journals, newspapers, and popular magazines alike have been carrying stories dealing with many aspects of the problem. Despite this unusual interest it is we mechanical engineers who really need to take a more serious look at the problems of meeting future demands for energy production. We are the professional group which will be most responsible for making critical decisions affecting the future in this area. Certainly, this has been our role in the past.

Decisions for the future will have to be made on new and different ground rules from those of the past. Coming at a time when ASME is reexamining its goals and priorities, it seems appropriate that we similarly devote much attention to energy production and utilization. Such review will necessitate major revisions in engineering priorities.

All of the information sources show that man is

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utilizing more and more thermally produced energy. Even with the population increase, the world-average increase in energy consumption per capita is moving ahead at about 3.5 percent per year (1963–1966 data). The same data show that the per capita growth in energy utilization on the North American continent is far ahead of the world's average. From the *Minerals Yearbook* [2],[2] North America consumes about 37 percent of the world total output. On a per capita basis this consumption is three times greater than Western Europe and at least 30 times greater than the Far East or Africa. Such data also indicate the huge disparity in the standards of living between people in backward countries and those in highly technologized countries.

However, it is becoming pressingly evident that our appetite for more and more energy is not without problems. People in this country are now aware of a severe pollution problem which is attendant to the ways in which we produce this abundance of energy. As is well known, most energy in the form of electricity or energy to supply our transportation needs is produced through the combustion of hydrocarbon fuels—petroleum, natural gas, and coal. Some of the products of combustion are pollutants to the atmosphere.

Aside from pollution, the demand for more energy raises questions about the depletion rate of the world's supply of fossil fuels. For how long will the reserves of these fuels last at the present rate of accelerated consumption? Regardless of whose estimates one believes the reserves have a limited lifetime.

Pollution and depletion of natural resources are difficult questions to confront. For the engineering community, they present some major challenges. Not only do major fixes on combustion hardware have to be devised and new means of "mining" the fuels have to be developed, but a more ambitious program to develop new sources and new means of producing energy must be inaugurated. The significant development in nuclear electric power is a first step, but there are also pollution problems with this advance.

Despite immediate efforts to control pollution and conserve fossil fuels, the development of new energy sources is imperative. Several new concepts have application in the areas of transportation and electrical power generation. But, new means of producing energy will not be without their concerns in creating new ecological and conservation problems. Any thermal system that can be conceived will involve losses and wastes of some sort. The second law of thermodynamics guarantees that there will be some kind of pollutant waste to deal with in any system.

Trends in Energy Consumption

The United States. The trends in the utilization of energy for transportation and electrical power consumption in the U. S. are evident from an examination of Figs. 1 and 2 [3]. The data are staggering in magnitude, and even more staggering in their extrapolation to the future. Consumption of gasoline and diesel oils has grown from 40 billion gal per yr in 1950 to 78 billion gal per yr in 1967—or almost double in that short time period. By 1980, if our consumption continues to increase at the present rate, we could exceed an annual consumption of 100 billion gal per yr.

According to the U. S. Geological Survey, the oil reserves in the continental U. S. and Alaska amount to approximately 200 billion bbl or 10,000 billion gal. This is a conservative estimate of these reserves. If we accept this figure and consume oil at the 1980 rate, we could use up all of our reserves in 100 yr. Even if these oil reserve estimates are off by a factor of 2, the depletion rate of our oil resources is an ominous development. There are some authorities who claim that our oil reserves will be used up in *less* than a century.

At the 1970 rate, we are burning about 400 gal of these fuels per year for every adult and child in the U. S. This quantity of fuel burned in internal combustion engines (based upon 1963 release estimates) releases about 150 lb of hydrocarbons, 800 lb of CO, and 45 lb of various oxides of nitrogen per year for every person in the U. S. [4]. Per automobile, this amounts to over a ton of pollution per year.

Admittedly, the new emission controls put on automobiles will reduce the pollutant rate per automobile per year drastically. The 1970 standards applied to all automobiles would reduce the emission to approximately one-third of the 1963 uncontrolled level. Certainly all of the autos on the road after 1970 will not measure up to these standards and the average total emission from each auto will be somewhere between the 1963 and 1970 levels.

If the consumption of auto fuels goes up as projected from Fig. 1, the future increased use will soon bring the total pollutant rate up to levels which are equivalent to or exceed the levels of the 1960s. It appears that reducing the emission rate per auto to the theoretical minimum will not permanently overcome the high pollution contribution by the internal combustion engine. In fact, it seems evident that more drastic measures will be necessary to cope with automobile-related pollution in the future.

Electric Power Consumption. The increased demand for electrical energy in the U. S. has averaged almost 7 percent per year during the 1960s [3]. The steady increase in the electrical power consumed is shown in Fig. 2. From this data it is anticipated that the U. S. will consume over 1500 billion kwh of electricity in 1970. By 1980, our demands probably will be doubled to reach 3000 billion kwh. If our consumption continues to double every decade, the electrical power consumption will reach a staggering value by 2000 A.D. of something like 10,000 billion kwh. One can only speculate how the power companies are going to provide such vast quantities of electrical energy. Expansion in generating capacity will come from three types of plants: (1) The fossil fuel burner (coal, gas, and oil); (2) the hydroelectric installation; and (3) the nuclear power plant. Despite a growing commitment to new nuclear plant construction, most of the initial increase will have to be assumed by the plants which burn fossil fuels. The hydroelectric plants are limited to places where natural conditions make it possible to tap a head of water. Generally these limited sites are far removed from populous industrial centers, so a greatly expanded

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[2] Numbers in brackets designate References at end of article.

hydroelectric capacity seems impossible—certainly in the U. S.

Currently, only 17 percent of the power developed in this country comes from hydraulic sources. Over 50 percent comes from coal burning, 23 percent from natural gas, and about 8 percent from fuel oil. The contribution from nuclear sources is negligibly small. There is a trend now toward conversion to gas or oil instead of coal as a fuel to overcome certain pollution difficulties.

The point is that the consumption of fossil fuels will go up at a tremendous rate if we try to respond to the greater demands for electrical power. This is the kernel of the problem. Can we in the U. S. meet the energy demands of the future without depleting fossil fuel reserves and spewing out vast quantities of pollutants?

Western Europe. Next to the North American continent, Western Europe is the largest consumer of energy in the world. As such it has a regional pollution problem because of intense industrialization. Fig. 3 shows the petroleum and coal consumption realized or estimated, from 1965 to 1980 [5]. The increase in petroleum consumption reflects both transportation and electrical energy demands. Although Europe has an ambitious program of developing nuclear power plants, fuel oil is being used at an increasing rate in place of coal. The substitution of oil for coal reduces pollution but aggravates the oil reserve problem. Coal is generally much more plentiful than oil in the world.

Means for Producing Energy

With some appreciation for the present and future demands for energy, let us look now at ways to generate it other than by the combustion of hydrocarbons.

Electrical Energy From Nuclear Fission. Currently, in the U. S., there is something like 70,000 MW of nuclear-electric power capacity under construction. It is estimated that by 1980 about 150,000 MW of capacity will be available. In Europe, it is anticipated that about 110,000 MW of nuclear-electric power will be ready by 1980 [6]. Despite this anticipated growth of nuclear-electric power in the U. S., it will still amount to only about 20 percent of the anticipated power needs in the 1980s.

The U. S. holds a key role in the development of nuclear-electric power over the entire world. First, the U. S. is the principal source of the enriched uranium used to charge the reactors. Second, we are the world's principal supplier of the reactor shells, heat exchangers, turbines, and electrical generation equipment. It is estimated that the U. S. capacity to produce enriched uranium must be doubled by the end of the '70s if the forecasted expansion of nuclear-electric power in the free world is to be achieved. Such an expansion in the near future requires immediate plans for adding capacity to existing uranium-enrichment plants.

There are some other developments in the wind that may affect the expansion of nuclear-electric power. One is the potential development of the fast breeder reactor which would drastically reduce the future need for enriched uranium. It is still too early to make any meaningful assessment of the success of such a reactor. At the present time, considerable research effort is being devoted to this type in both the U. S. and Europe. An

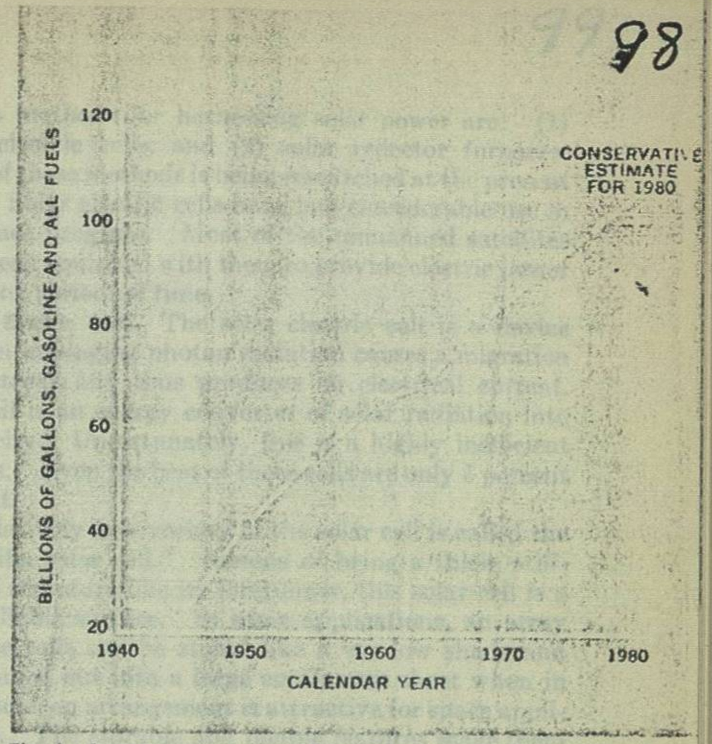

Fig. 1 Annual consumption of fuels for cars, trucks, and buses (from the Department of Transportation).

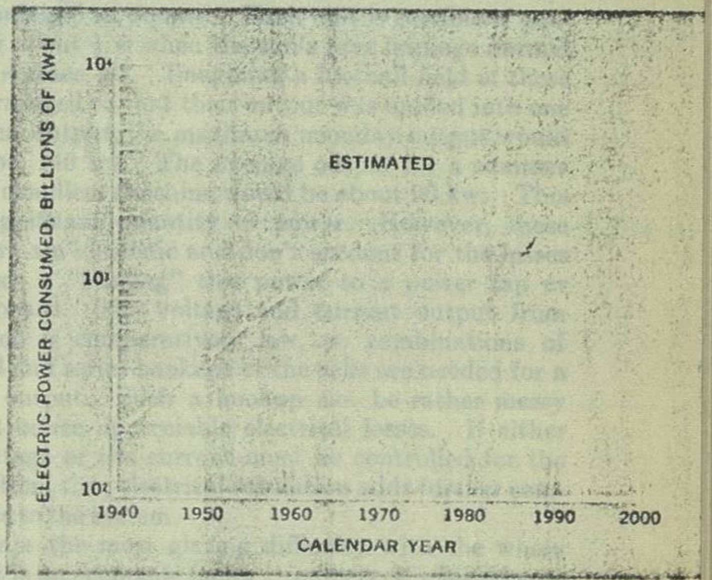

Fig. 2 Electrical power consumption in the United States.

Fig. 3 Consumption of energy in Western Europe according to fuel burned.