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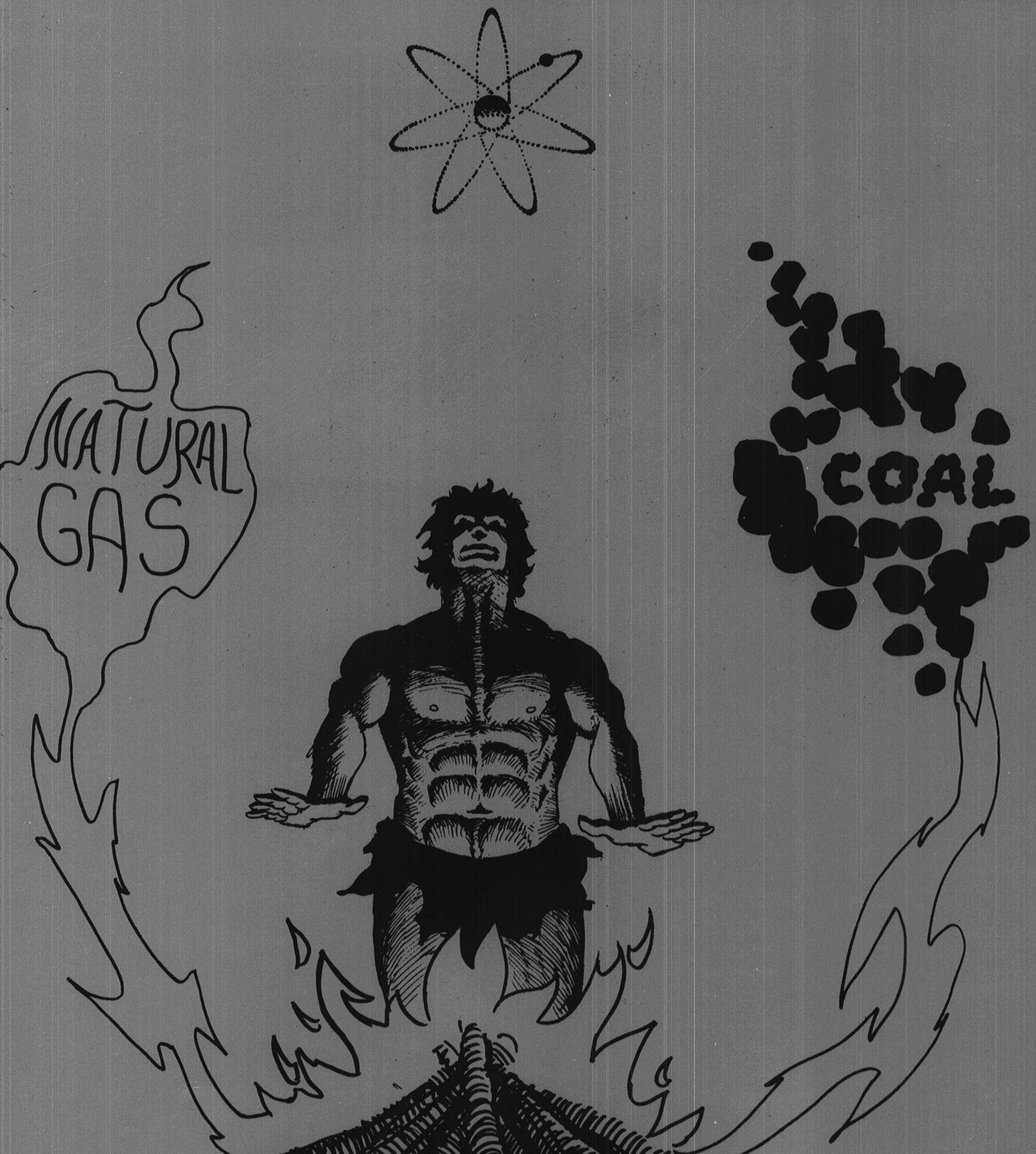
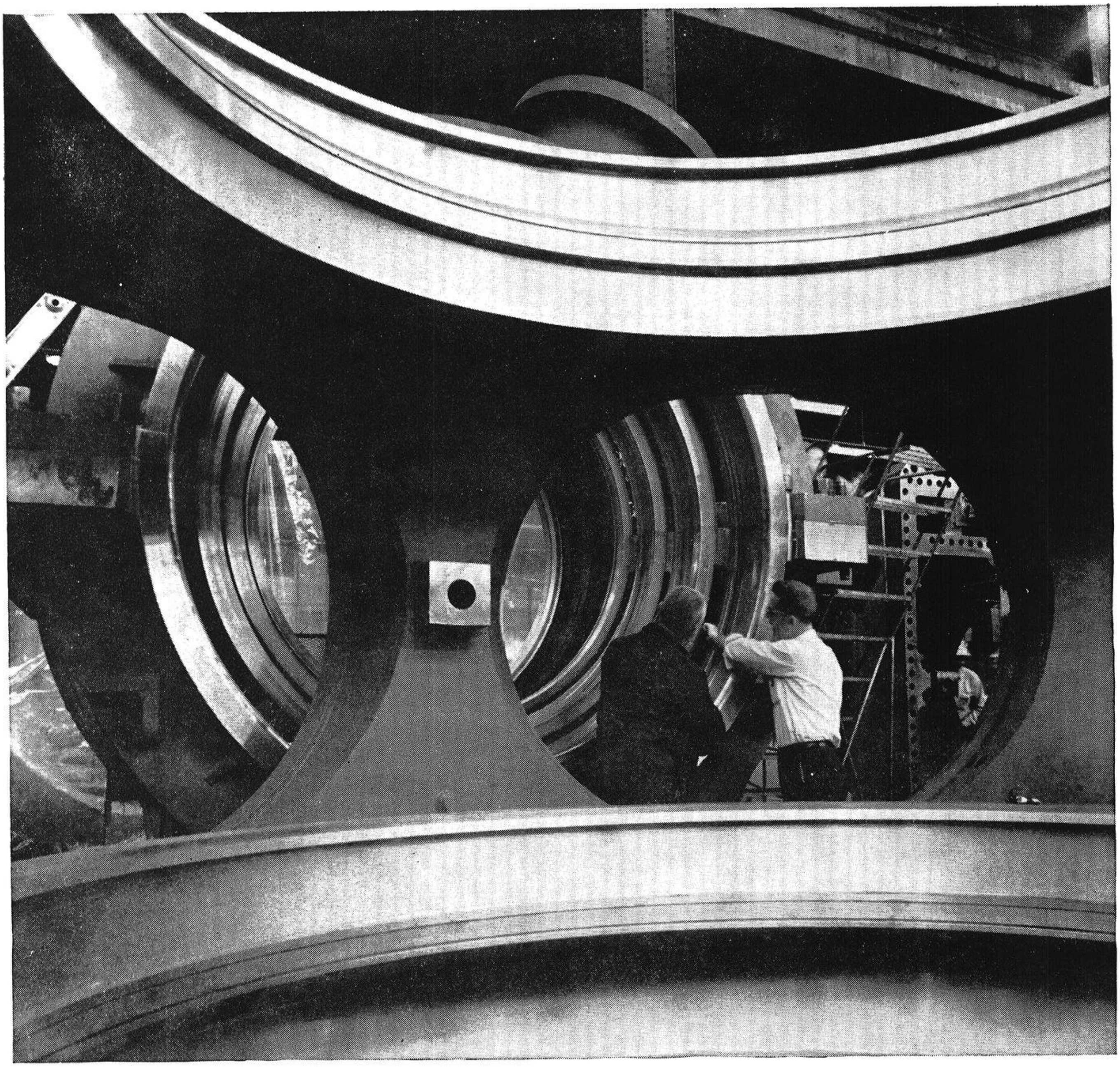
wisconsin engineer





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DEAN MARSHALL COMMENTS:

The Question of Professional Dissent

In the *Wisconsin Engineer* for December, 1972, the lead article was entitled "California's Giant Water Hoax—How It Was Engineered." There are many important implications in this article for engineering students and for the engineering profession. These implications deal with the problems of professional responsibility, with the problems which complex socio-political-technological projects pose for engineering practitioners, with the problems of informing the public about engineering, and with the problems of informing the politicians and the decision-makers about engineering projects and engineering costs. The article quotes from a report of the Ralph Nader Task Force on "Land Use in the State of California." Of necessity, therefore, it is incomplete in terms of engineering detail; it also suffers somewhat in its use of the emotional descriptions of the project as a "boondoggle" and a "fraud." If one ignores these emotional accusations of the project and considers rather the complex socio-technical environment in which the project was undertaken, it provides the reader with a picture of the complexities and pitfalls associated with large engineering projects to solve problems of society. The California Water Project, if one believes the report (and without information to the contrary, one has to accept the Task Force Report at its face value), would appear to have grossly misinformed the public in terms of costs, expenses, and taxes.

One of the serious and most unfortunate aspects of the project appears to have been the behavior of the engineering consultants brought in to advise the State of California. The record seems to be clear that one of the five engineering consultants did not agree on the results of the Board's study of the DWR. Disagreement is valuable and essential. However, in this instance, the majority of the consultants for some incredible reason refused to present the minority or dissenting report of Mr. Adloph J. Ackerman, a member of the Consulting Board.

The fact that the project and its beginnings are a matter of recorded history provides an opportunity to evaluate the controversies which took place over a decade ago. Indeed, the present day information would appear to vindicate Mr. Ackerman's dissenting position and to show that if he had been listened to at that time, alternative decisions and courses of action with regard to the project could have been made. Certainly time has shown that the estimates of cost were grossly inadequate, that the cost to the taxpayers was and is vastly greater than originally represented, and that the effect of the project on the credit of the State of California has indeed been adverse.

For the student of engineering it would be worth his time and effort to study what indeed happened in the California Water Project, and what was the responsibility of the engineering profession. Could the engineering profession and individual engineers at that time have done a better job of presenting the engineering and economic facts to the public? In light of this experience, can the engineering profession now develop better ways of informing the public? Does the profession have to rely on the press and its politics to provide accurate, nonpolitical information, or can there be a new media for public information on technology? All of these questions and their answers are extremely important to the practicing engineers of the future, and it would be well, I am sure, to have studies of this kind reviewed and analyzed for the benefit of the engineering profession of the future.

Certainly the facts which can be obtained at this time would indicate that over a decade ago, the conscientious and dedicated effort of professional engineers, such as Mr. Adolph Ackerman, were fruitless and ineffectual. Why was this so? What were the factors which weighed against his effort to bring information to the public?

Intimately associated with the complex issues of that time were matters dealing with economics, with with the analysis of costs, with the projection of costs, and with an understanding of the impact of inflation on engineering projects. Is it possible that this area of engineering economics has been somewhat neglected in our engineering education, and that for the practicing engineer who will be functioning at the interface of society, both in the political interface as well as at the public and environmental interfaces, a sound knowledge of economics, of costs, of inflation, of taxation, of credit, is fundamental to his practice and to his obligations to his clients and to the public? Therefore, I would urge that a study of this particular project be undertaken as part of our engineering education so that we might learn from history, from past programs, past projects, past mistakes, and provide better direction and better education to our engineers of the future.

Finally, there is a very intersting and challenging implication underlying the entire article. This is the question of the degree to which the engineering profession will consent to have dissent arise within its ranks. Is it possible that professions in general—engineering, law, medicine—have endeavored for so long to present to the public the image of uniformity, tranquility, lack of dissent, such that we do a disservice to the public? Is it wrong to suggest that there can be major disagreement on large major engineering projects? Should such disagreement or dissent be properly and professionally presented, explained, rather than have it become a festering sore within a profession?

The question of professional dissent might be a subject of considerable concern in the educational community during the years ahead. What should be the role of engineering education in teaching engineering professionals of the future how to dissent in a professional manner?

W. Robert Marshall

Adlai Stevenson:

"Nature is neutral. Man has wrested from nature the power to make the world a desert or to make it the deserts bloom. There is no evil in the atom."

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The Cover —

This issue is primarily devoted to energy; how to obtain it, and use it. The cover suggests that ultimately man will replace more conventional energy sources with energy from the atom itself.

MEMBER OF ENGINEERING COLLEGE MAGAZINES ASSOCIATED

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NUCLEAR ENERGY:

Potential for Closing 'Energy Gap'

by Jeff Anderson

Is the United States facing an energy crisis? Understanding a question so complex requires an in depth look at the total energy picture. The United States has large reserves of energy including fossil fuel and uranium deposits that could last thousands of years. Why should a nation with the energy resources this one has be facing an energy crisis?

The present crisis is one of availability. Shortages have been produced by the placing of restrictions on the usage of fuels containing high concentrations of sulfur. This severely limits the use of coal. Oil and natural gas production have reached their peak in the continental U.S. while nuclear power plants have been delayed because of construction problems and public pressure. All these developments together are producing an "energy gap."

In the next 15-30 years there will be a much greater demand for energy than can possibly be supplied by domestic fossil fuel production. Perhaps the only way this "energy gap" can be closed is through the quick arrival of a dominant nuclear industry in the electric utility field. This article will try to explain the reasons why the U.S. faces an "energy gap" and why nuclear power may be the best alternative.

Coal is the most abundant natural resource in this country. At least 390 billion tons are known to exist in the U.S. This would be enough to last 600 years at the present rate of consumption. The Environmental Protection Agency is demanding that utilities, the largest single user of coal, sharply reduce their consumption because large amounts of sulfur dioxide, nitrous oxides, and particulate matter are produced when coal is burned.

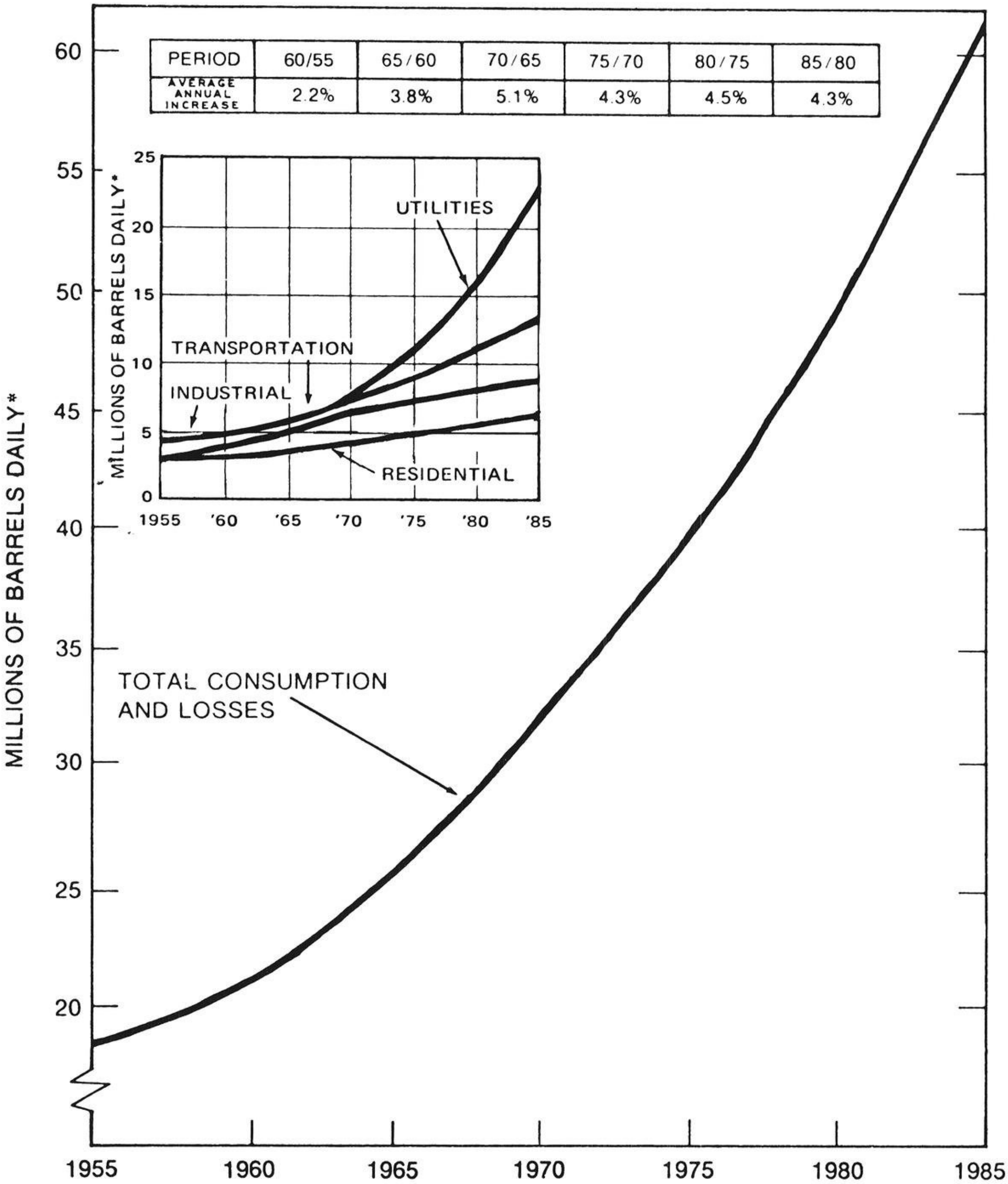
Natural gas is undoubtedly the best fuel available today. It is a clean, inexpensive fuel that today supplies 33% of the nation's energy. Unfortuantely, the price, regulated by the Federal Power Commission (FPC) since 1954, has been set so low that natural gas companies have recently been unable to afford to drill new wells. According to the FPC, the number of wells drilled in 1970 was only one half of the number drilled in 1956. The U.S. Geologic survey has estimated that there is as much as 6600 trillion cubic feet of natural gas still undiscovered in the U.S. If the price were allowed to rise, new reserves might be discovered. The FPC probably feels that it is preferable, from an environmental standpoint, to keep natural gas economically competitive with sulfur laden fuel oil.

The total U.S. consumption of natural gas was 22.1 trillion cubic feet (tcf) in 1970. During the same period only 11 tcf of new reserves were discovered. Since 1967 consumption has far exceeded the amount of new reserves found. Present consumption rates are very close to the maximum U.S. production capacity of 24.8 tcf. According to "Pipeline and Gas Journal" (Oct. 1972) the 1971 demand exceeded the supply by 6.2%. The Federal Power Commission states that the demand for natural gas will continue to rise at the rate of one trillion cubic feet a year.

Clearly this demand will be difficult to meet. By 1974, if present trends continue, production in the continental U.S. will decline. Gas from Alaska's Prodhoe Bay will not be available until after 1980. (That is assuming that the controversy over the Alaskan pipeline can be resolved.) Coal gasification has become a possibility with the successful operation of several pilot plants, but full scale commercial production is questionable before 1980. Another Alternative that is becoming increasingly important is liquified natural gas (LNG) imported from Africa and the Middle East. LNG importation takes place presently only on a limited scale, however, because of the large capital investments required for transportation. Also, environmentalists have blocked attempts at building special LNG docks in the U.S. This all adds up to a shortage in the availability of natural gas.

This shortage has forced many industrial consumers to convert to fuel oil. The increased demand from industry and the cold winter weather has caused a serious shortage of fuel oil. During the week ending December 1, 1972, according to "Oil and Gas Journal" (Dec. 11, 1972), this country produced a record 2.83 million barrels of fuel oil per day. And this was not even close to the demand of 3.4 million barrels/day. During that week alone, 2.4 million barrels had to be taken from the stockpiles which now stand 30.5 million barrels below what they were last year. If present trands continue, stocks of fuel oil will be exhausted within seven years. Crude oil production in the continental U.S. is on the decline, leaving Alaska as the best hope for new resources. But oil from Alaska would not be available until after 1977 even if the Alaskan pipeline were begun today. At full production Alaska's Prodhoe Bay would add only two million barrels (bbls) a day, just a small fraction of the total projected demand.

U. S. ENERGY CONSUMPTION



PERIOD	60/55	65/60	70/65	75/70	80/75	85/80
AVERAGE ANNUAL INCREASE	2.2%	3.8%	5.1%	4.3%	4.5%	4.3%

SHELL OIL – HOUSTON
FEBRUARY, 1972

*CRUDE OIL EQUIVALENT

Nuclear Energy (cont. from p. 4)

While domestic crude oil production has reached its peak, demand continues to climb. Already 17 million barrels of oil are consumed each day in the U.S., while Shell Oil estimates that by 1985 the demand will be 30 million barrels/day. Unfortunately, the demand forecast for 1985 is largely fixed. Registration of motor vehicles is expected to increase 40% by 1985. Larger suburban populations and more multiple car families will cause the consumption of gasoline to nearly double in fifteen years. The added increase in demand for heating oil and jet fuel will keep oil the most important single source of energy in 1985. Oil meets 44% of today's energy requirements, and this figure may even increase to about 47% by 1985.

Shell estimates that about 60% of the crude oil refined in the U.S. in 1985 will have to be imported. This presents a problem in national security. Mr. Gerald C. Gambs of Ford, Bacon and Davis, Inc. put it this way before the ASME fossil fuel crisis panel: "It is completely impractical to assume the U.S. can function as the world's most industrialized country if we are only able to supply one half or so of our oil and gas requirements from domestic sources." The Middle East, with nearly 75% of the free world's oil, could supply our needs well beyond the year 2000 when nuclear fusion and other cleaner and more efficient sources of energy should be available. Many times in the past the Arabs have shut off the supply of oil. When over half of the U.S. oil supply depends on other countries, this country will have put itself in a potentially dangerous situation. Clearly a better solution should be sought.

In looking for a solution to the energy problem, one needs to know which segment of the economy will be the largest consumer of energy by 1985. Recent figures compiled by the Chase Manhatten Bank's Energy Economics Division show that electric utilities will probably consume 38% of the energy market in 1985. This is an increase of almost 300% over the 1970 value. Other segments of the economy will increase from an estimated minimum of 44% (residental) to a maximum of only 80% (transportation).

Energy consumption in million bbls./day
(crude oil equivalent)

Consuming segment	**1970**	**1985**
Industrial	10.7	16.9
Electric	8.0	23.2
Transportation	7.5	13.5
Residential	4.5	6.5
Commercial	1.8	3.0

Source: Chase Manhatten Bank, 1972 reprinted in "Pipeline and Gas Journal" Oct. 1972. Clearly the electrical segment of the economy is the place where the battle to close the energy gap will be won or lost.

Nuclear power plants are well suited for central station power generation and produce a much different picture than fossil fuel plants. According to the FPC, the total installed nuclear capacity by 1980 will be approximately 150,000 Megawatts. The amount of fossil fuel that would be required to power just the nuclear capacity in 1980 would be either 15 million tons of coal/day, 65 million bbls oil/day, or 290 billion cu. ft. of natural gas **per day.** To power the entire 1980 projected electrical capacity of 658,000 MW with fuel oil would require 240 million bbls per day. This is 14 times the present daily consumption of 17 million bbls/day. While the need for nuclear power is obvious, it is also true that all electric generating cannot be nuclear. Fossil fuel plants will still have to meet the periods of peak demand because their output can be varied more easily while nuclear plants normally stay at full power 24 hr./day. But nuclear power will relieve a large share of the burden on fossil fuels. A Consolidated Edison official recently pointed out that his company's 200 MW nuclear unit used 2800 lbs. of uranium to produce nine billion kwh instead of burning 4 million tons of coal and producing 400,000 tons of ash, 280,000 tons of SO_2 and 800 tons of particulate matter.

There is at least a thirty years' supply of uranium even with the increased demand taken into account. The real benefits of atomic power, however, will come with the perfection of the breeder reactor which produces more fuel than it consumes. While U-235 is the only naturally occuring isotope that will undergo fission, two other isotopes can be made. The U-232 and U-238 both abundant in the earth's crust, can be U-238, both abundant in the earth's crust, can be placed inside the core of an operating nuclear reactor. The two isotopes capture excess neutrons from the fission reaction and after subsequent beta decays form the fissionable products U-233 and Pu-239.

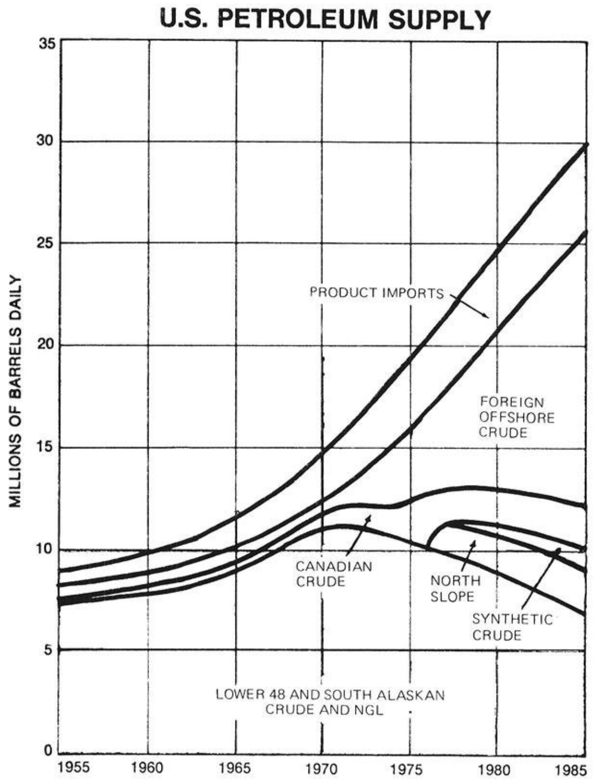
$$Th^{232} + n \qquad Th^{233} \qquad U^{233} + 2B-$$
$$U^{238} + n \qquad U^{239} \qquad P^{239} + 2B-$$

With breeder reactors the supply of fissionable material becomes virtually unlimited. But we don't need the breeder to solve our energy problem today. There will be enough uranium 235 available to satisfy the needs of a rapidly expanding nuclear power market throughout this century.

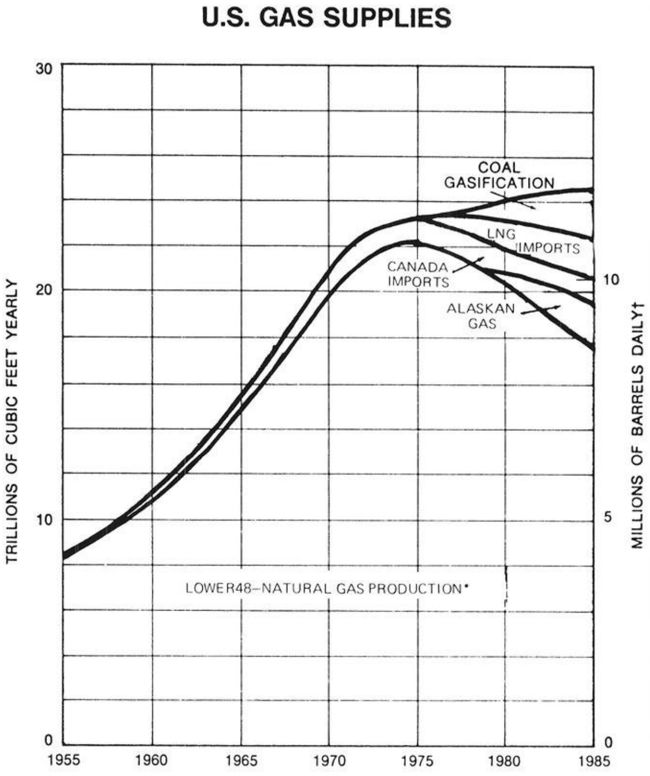
The nuclear industry has had its problems in the past. When the big push to nuclear power started in the sixties, the industry experienced delays in construction and delivery on components. Another problem was public resistance to atomic power. Too many people still have unwarranted fears of a nuclear accident.

The truth is that nuclear power plants are extremely safe because of the many safeguard systems added in the design. For example, if all the control rods of a reactor were pulled out, the reactor would not run wild and explode like an A-bomb. Should that happen, the reactor output would level off without outside interference. This is an internal property built into the reactor itself. It could never, under any circumstances, explode.

The most dangerous accident that could occur is a loss of coolant. If a reactor running at full power suddenly lost its flow of cooling water, the reactor would heat up very quickly and part of the fuel would most likely melt. To guard against this, every plant has several back up cooling systems that would take over if the primary system failed. Even if all the cooling systems failed, the thick concrete containment vessel in which the reactor is placed would trap any radiation released from a meltdown of the reactor core.



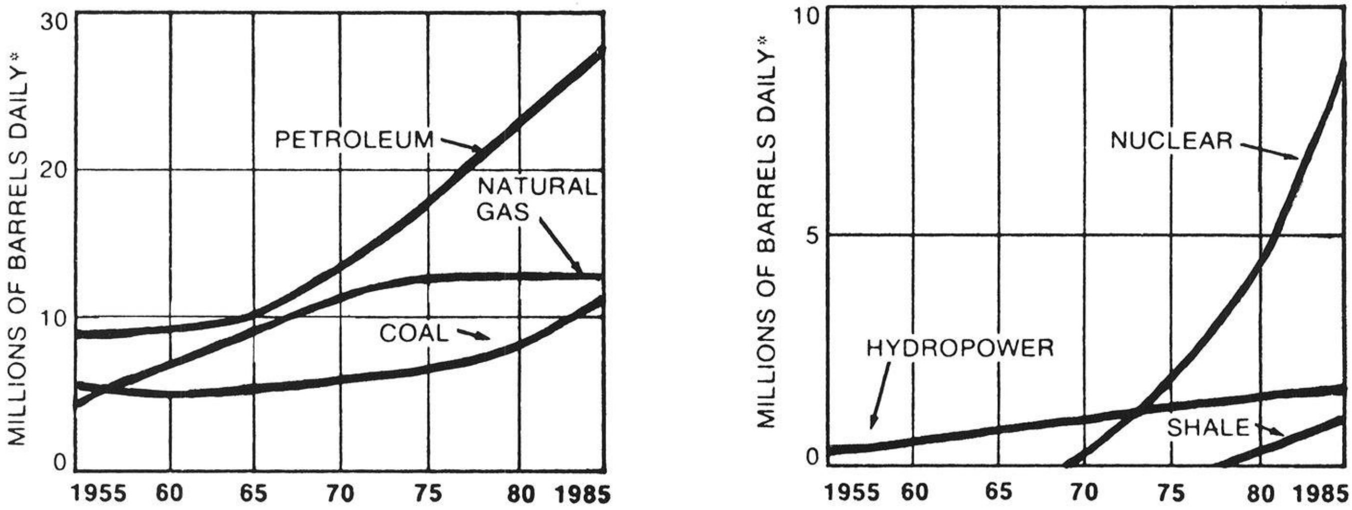
SHELL OIL – HOUSTON
FEBRUARY, 1972



SHELL OIL – HOUSTON
FEBRUARY, 1972

*NET PRODUCTION AFTER TRANSMISSION LOSSES AND INVENTORY CHANGES
†CRUDE OIL EQUIVALENT

U.S. ENERGY SUPPLY



Nuclear Energy (cont. from p. 6)

Some well publicized reports on the possibilities of a nuclear accident also assume that at the same time all of these failures within the plant are happening, something like an earthquake or direct attack destroys the thick containment vessel.

Clearly, if all these accidents occurred simultaneously, the results would be serious. However, the probability of such an occurance is extremely small.

The public also worries about the dangers of radiation. But man has lived with a significant amount of natural radiation for a long time. Radioactive releases from plants are strictly controlled by the AEC. On site measurements have shown that the amount of radiation received at the boundary is only .1 (MREM) per year. This compares favorably with the natural background count of 125 (MREM) per year. Even in the year 2000 with approximately 55% of the power plants nuclear, the population should receive only 1 (MREM) in additional yearly dosage from all the operating plants.

The two major problems that still exist are radioactive and thermal wastes. Nuclear plants discharge from 50 to 60% more waste heat into the cooling water than fossil plants of similar size. This is less of a problem today than it will be in the future. If present trends continue, by the year 2000 power plants will produce enough waste heat to raise the temperature of the total fresh water runoff in the U.S. by 24°F. Cooling towers and ponds are relieving a portion of the problem, but it will not be enough. Planners are hoping that public acceptance will permit siting of tion. But man has lived with a significant amount of waste heat can be used for industrial and residential heating.

Probably the most potentially serious problem which faces the nuclear industry is the disposing of large amounts of radioactive wastes. Present techniques are adequate today, but it is clear that with an expanded industry much more effective procedures will have to be found. Both of these matters require continued research to determine whether further corrective measures are necessary.

In recent years the position of the nuclear industry has improved. "Electric World" (Oct. 15, 1972) now reports that lead times, periods between planning and completion, have stabilized at seven years so that from now on plants should be finished on schedule. With the industry settling its own delay problems, new orders for nuclear reactors have increased tremendously. The "Edison Electric Institute" confirms that one half of the total generating capacity ordered in 1971 was nuclear. The orders continue to mount, according to "Electric World," which has recorded 145 new plants ordered from January to August of 1972. With these new plants coming on line within the next 10 years, a crisis could be averted. Delaying plants even six months could result in a loss of 113 million bbls of precious fuel oil. The White House Office of Emergency Preparedness recommended in a recent report that delays in nuclear plant construction could be eased by "accelerating site review provisions and resolving radiation controversies quickly." The Atomic Engergy Commission is working with other agencies to revise its licensing requirements so that nuclear plants can be built without unwarranted delays. This is important to our chances of surviving the mounting "energy gap."

Nuclear power is the only energy source that could be available within the next few years in the quantities required to meet U.S. needs. The government has waited so long that it is now too late to avert a crisis by dramatically decreasing the need for energy. Instead we must concentrate now on formulating a comprehensive, workable energy policy covering all segments of the energy market.

Some suggest that rate schedules be changed so that large volume customers pay a more equal share in the added fuel costs occurred from pollution control programs. Others feel that guidelines or regulations controlling the maximum and minimum temperatures of buildings would reduce fuel requirements for heating and air conditioning. There are authorities who feel that rationing is necessary, while others feel that the energy market would take care of itself if all government controls were removed. Clearly we need time to establish a sound energy policy. Increased use of nuclear power will give the government the time it needs to formulate a policy so that an energy crisis can be averted in the next few decades.

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Mr. Carbon

NE Chairman Explains Design of Fusion Power Plants

Reprinted from UIR/Research Newsletter, Summer 1972, Vol. 7, No. 1

Max W. Carbon
Chairman of the Nuclear Engineering Department

ONE GREAT NEED OF THE NATION AND WORLD is coming years will be for additional electricity generated by pollution-free methods. This need, in fact, is becoming critical.

In theory, controlled thermonuclear fusion offers the means to meet this need, and researchers throughout the world are becoming quite enthusiastic and optimistic that controlled fusion will be scientifically demonstrated within three to five years.The nature of the reaction requires high temperatures which allow high thermal efficiencies. In addition, induced radioactivity will be much less than in fission systems.

No broad, integrated study was yet been made of the design of a fusion reactor — a device for transforming energy released in the controlled-fusion process into economic, useful electricity. In fact, no one can surely say today that success in fusion research can be translated into useful power. The need to explore the generation of useful power from the fusion process is urgent. An engineering team has been assembled at Wisconsin to carry out the preliminary design of a practical power plant. The study will involve about twenty staff members and ten graduate students under the direction of Prof. Harold K. Forsen of the Nuclear Engineering Department and will cost about $1,000,000.

Present Situation

A large amount of power is generated in the United States each year. Even larger amounts would be desirable if the environmental cost is not too high and if we do not exhaust energy resources too rapidly. More power would allow us to maintain current standards of living as the population increased. It would also permit us to raise standards of living for "have-nots"—ghetto and inner-city people in general. In addition, a successful attack on environmental problems will require more power. For example, use of electricity to treat sewage and water is expected to double between 1968 and 1973. An electrostatic scrubber to remove pollutants from the smoke discharged by an industrial plant may require 50,000 kilowatts of electricity.

In some cases it might also be desirable to switch from one kind of energy to another. For example, gasoline engines cause air pollution. The development of adequate batteries so that automobiles could run on electricity might greatly reduce our smog problems. Further, since it is estimated that 60 percent of our oil will come from foreign sources by 1985, development of this battery-generation plant could have profound foreign-policy implications also.

Twenty-five percent of the total power produced in the U.S. is in the form of electricity. It has been estimated that that fraction will rise to 50 percent within thirty years. Most electricity now comes from the burning of about 500 million tons of coal per year. Some of the factors involved in burning coal include:

1. Thermal pollution,
2. Atmospheric pollution,
3. Safety of mining coal,
4. Safety of burning coal and generating electricity,
5. Cost of producing electricity,
6. Rate of depletion of our coal reserves.

Four of these factors are negative: atmospheric pollution is higher than desired, 80,000 coal miners have been killed in mine accidents since 1910, coal reserves will be used up in a few centuries at present consumption, and thermal pollution is becoming a serious problem. The remaining factors are positive. The safety of burning coal is unquestioned. The cost of producing electricity has been reasonable.

Today, the utility industry is turning to nuclear energy in thermal reactors for power production. Atmospheric pollution by combustion products is eliminated, and the cost of producing electricity is lower or at least no higher when large plants are used. However, present-day or thermal reactors have at least three disadvantages: nuclear fission will provide at least half of our electricity within thirty years but we have only enough uranium to supply energy needs for two or three decades using that kind of reactor, thermal pollution is worse than for coal plants, and many people are not convinced reactors are safe. They are concerned primarily about the theoretical possibility of catastrophic reactor accidents and about the fact that atomic wastes must be stored for thousands of years before they become harmless.

The government and industry are jointly working to develop a new type of reactor, the so-called breeder. These reactors have two major advantages over thermal reactors: first, fuel can be manufactured so that our supply of uranium will last for centuries instead of decades and, second, efficiencies can be increased so that thermal pollution will be no worse than for coal plants. Plans are under way to build a large breeder-demonstration plant within the next six or seven years. It is expected that the breeder reactor will be in commercial use by 1985.

It is hoped that breeder reactors will offer significant advantages over coal plants in matters of atmospheric pollution, costs, and rate of using up our resources. However, although most technical people working in the field are convinced that breeder reactors are safe, many members of the public are not.

Fusion Power

The reactors discussed above are fission reactors in which uranium nuclei split and give off energy when neutrons are captured. In fusion, energy is released when two light-weight nuclei collide at high speeds and fuse together.

Scientists and engineers engaged in fusion research, or plasma physics as this is called, are optimistic that they will have the knowledge to design net-energy-release experiments in two or three years. The Russians have led the way with their Tokamak machines, and Americans and others are now doing similar experiments.

Nations of the world are spending about $100 million per year on fusion research, but no one has undertaken a systematic study of how to convert fusion energy to useful power. We expect early fusion reactors to "burn" deuterium (obtained from water) and tritium (bred by the capture of neutrons in lithium). Most of the energy will be produced in the form of kinetic energy carried by the neutrons released in the D-T reaction. The reactors will be very complex devices. In any design effort, problems will likely be encountered in areas such as

plasma physics — confining plasma, igniting it, fueling it
Neutronics — neutron transport, dissipation of energy from neutrons, breeding of tritium with neutrons, generation of radioactivity
heat transfer — cooling with liquid metals in a magnetic field, cryogenic problems
materials problems — preventing wall materials from disintegrating under radiation bombardment
superconductors — design of cryogenic, superconducting magnets
safety analysis — handling of radioactivity
economics
structural design
systems engineering — fitting everything together.

The Future

What effect could fusion reactors have on the production of electricity and the problems of society?

1. Fusion reactors will operate at higher temperatures with higher efficiencies than fission reactors, and thermal pollution will be decreased. In the long-range, direct energy-conversion schemes may be possible with essentially zero thermal pollution.

2. There will be no combustion-product release and essentially zero atmospheric pollution.

3. The cost of producing electricity is unknown at this time. However, fuel costs will be quite low and the potential exists for very low-cost electricity.

4. If our fuel comes from water and lithium as will be likely in early reactors, we may have only enough lithium to last a few centuries. However, later reactors may operate on fuel from water alone. The oceans may contain enough fuel to supply our needs far beyond our ability to predict them.

5. The actual process of generating electricity will be very safe.There will be considerable radioactivity—structural materials will become highly radioactive and large inventories of radioactive tritium may be present. However, it should be possible to demonstrate very easily to a questioning public that the process is safe. Positive answers exist to all four safety questions which are likely to be raised: (a) a fusion reactor is a fail-safe device which cannot run away—even in theory—if something goes wrong; (b) the radioactive materials in a fusion reactor will have half-lives of only a few years; potential damage in an accident is relatively small; (c) for the same reason there is no problem of storage of waste material for thousands of years, and (d) although firm figures are not available, it would appear that there would be a thousand or ten thousand times less radioactivity around a fusion plant than a fission plant.

Thus fusion reactors hold great promise. It is reasonable to dream of utilizing many times more power than we do now with almost zero deleterious effects to environment or other aspects of society.

Let me add a word of caution: we won't have fusion power in four or five years. The very best that can be hoped for would probably involve operation of an experimental plant by 1978 or 1980, operation of a middlesized prototype plant costing several hundred million dollars by 1986-1990, and operation of the first full-scale, commercial power plant by 1994-2000. We always seem to be too conservative as we look into the future, but it would not seem prudent to make large national commitments based on shorter time scales.

To summarize:

The nuclear fusion process holds great potential for providing unlimited electricity under safe conditions and with low pollution. Since extremely high temperatures are involved, high thermodynamic efficiencies are probable, and direct energy conversion techniques may be possible.

No organization or group of people anywhere in the world has yet undertaken a systematic study of the problems involved in converting fusion energy to useful electricity. Any practical conversion scheme will involve a large engineered device designed by a competent team of specialists who will approach the problem on an integrated technical and economic basis. The Wisconsin study is thus a pioneering effort.

Under optimum conditions it will be as much as twenty years before a practical fusion reactor will be available. The objective of the project as proposed by Wisconsin engineers is to show on as short a time scale as possible that useful power can be generated from fusion energy.

This study started last September, and it has been financed by seven Wisconsin participants: Lake Superior District Power Company, Ashland; Madison Gas and Electric, Madison; Northern States Power Company (Wisconsin), Eau Claire; Wisconsin Electric Power Company, Milwaukee; Wisconsin Michigan Power Company, Appleton; Wisconsin Power and Light Company, Madison; Wisconsin Public Service Company, Madison; Wisconsin Public Service Company, Green Bay. Northern States Power Company of Minnesota is also a major contributor.

Fusion: Principles and Potentials

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THE UNITED STATES IS FACED with serious power problems. Coal and fuel oil meeting new air quality standards are in scarce supply. Rich oil and natural gas fields created over eons of time are being depleted in decades. Clearly new energy sources are needed.

An energy system molded after the sun, the earth's major source of energy, maybe the ultimate answer to multiplying demands for clean, dependable power.

The fusion process is nothing new to science. During high energy accelerator experiments 40 years ago, physicists observed that hydrogen atom nuclei accelerated to great energies overcame normal replusive forces between charged particles and fused together. The fusion produced energy. But much more energy has to be added to achieve sustained fusion than is produced by the occasional fusion of two nuclei. Fusion reactions, unless in large quantities, cannot produce usable energy.

In a one quart container of deuterium and tritium at atmospheric pressure and heated to 100 million degrees, fusion reactions predominate, releasing energy at a fantastic rate—about 100 million kilowatts or roughly 10 percent of estimated need for the entire United States during 1975. High temperatures and pressures encountered point up some of the technical problems involved in making fusion power a reality. Solid containers have been ruled out. Either the vessel would cool the plasma, quenching the reaction, or the plasma would damage the walls of the container. To overcome these problems, "magnetic bottles" designed to hold the plasma are used (See UIR/Research Newsletter, November, 1969, and Winter, 1971).

Professor Donald W. Kerst explains: "The product of plasma density and confinement time must be a certain known value for a self-sustaining fusion reaction. This is the minimum value researchers are shooting for."

Many different kinds of plasma-studying devices are in use. All contain the plasma within a magnetic field for the life of a plasma experiment, usually less than 50 thousandths of a second. Some are open-ended, with linear magnetic fields and "mirrors" at either end. Quiet, stable plasmas are difficult to achieve with these devices. In addition, plasma can easily "leak out'" the ends of the machine.

Early in 1970, the Wisconsin levitated torodial octupole, an example of a closed system, went into operation. Built to minimize magnetic field errors inherent in a smaller device built in 1964, the machine was fabricated at UW's Physical Sciences Laboratory with funds from the Atomic Energy Commission and is described in a separate article.

"This kind of machine isn't intended to be a nuclear fusion reactor," Professor Harold Forsen cautions. "But the experiments we run with cool plasmas give us a lot of information on how plasmas act, and how changing magnetic fields and symmetry effects can alter a plasma's stability and confinement time. These results are direction signs on the path toward fusion power."

One of the recent advances in plasma research came from a Russian-built closed device called Tikamak T-3, located near Moscow. Fusion reactions have been observed on the T-3, but not at a sufficient level.

A major problem facing fusion research groups throughout the world is the lack of adequate scaling laws. If larger research devices are built or larger magnetic fields employed, how will plasma confinement time vary?

Future Prospects

Once achieved, a workable fusion power system would have many advantages. In a world increasingly aware of its delicate ecological balance, many of these stand out as environmental plusses.

Depending on the fuel cycle and the type of reactor, direct conversion fusion reactors might achieve efficiencies of 80-90 percent. Present fission reactors operate at efficiencies of about 30 percent while conventional power plants and improved fission systems approach 40 percent.

The most likely candidate for the first fusion power plant is the deuteriumtritium reaction, producing an impressive 17.6 million electron-volts of energy per fusion. Deuterium occurs naturally in sea water, and the technology to extract it easily has been known for more than twenty years. Enough deuterium reserve are present in the world's oceans to last thousands of years. Tritium does not occur naturally, but several ways have been suggested to "breed" the tritium needed for the fusion process directly within the reactor itself.

The scientific feasibility of controlled thermonuclear reactions, or fusion, may be demonstrated in this decade. The possibility of a demonstration reactor is foreseen some time in the 1990's with a commercial plant probable around the year 2000.

The "next generation" of power sources promises to provide abundant power from inexpensive fuel with fewer problems of pollution, waste disposal, and safety than fission power plants. Fusion is fundamental to the evolving national energy policy.

Fusion reactors would produce easily manageable radio-active products. This is in contrast with unavoidable problems faced by fission power plants—for every pound of radioactive uranium fuel, several pounds of radioactive waste is produced, creating ever-increasing disposal problems.

Fusion systems also have the definite advantage of low waste heat production.

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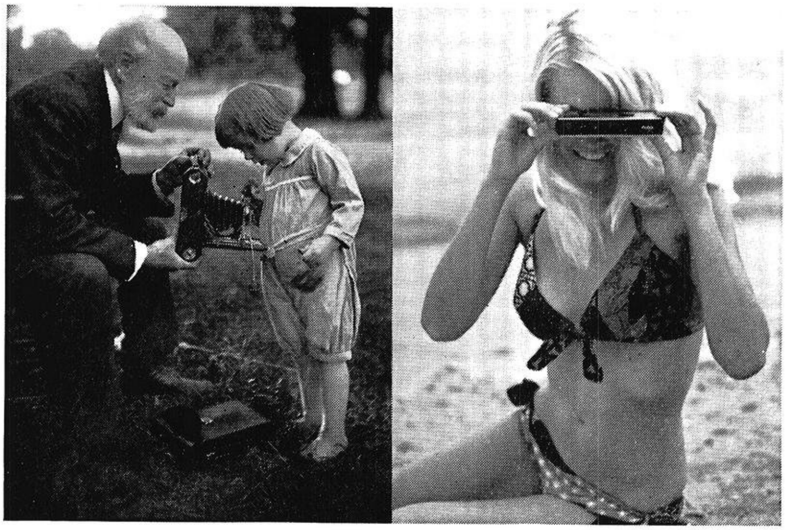

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