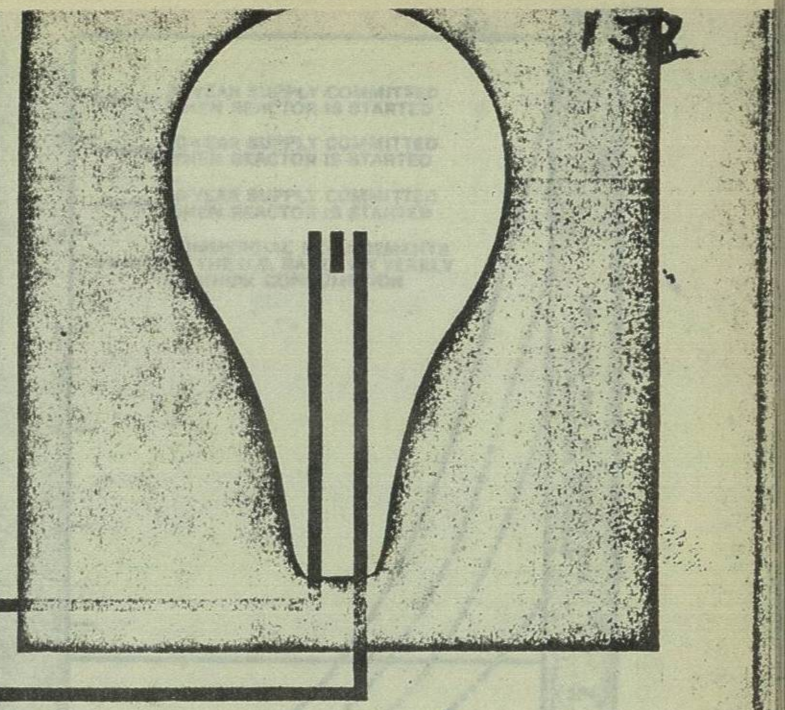
MHD CENTRAL POWER: a status report



MHD offers unmatched advantages: high thermal efficiency (50 to 60 percent), no air pollution other than CO_2, and no radioactive waste. And it may shrink the nation's power bill by $40 billion to $130 billion. Other countries, particularly the Soviet Union, are investing large efforts in MHD. We are dragging our feet. In light of the fact that our uranium supply is running out and the breeder reactor is still a question mark, we must reexamine our priorities.

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On June 4, 1971, President Nixon released a message to the Congress concerning the energy crisis. The main thought of the message was to ask for more money for the nuclear breeder reactor. It is obvious from the timetable given, which sets a goal of 1980 for demonstration of the breeder reactor, that such devices will not be available in time to alleviate the impending uranium shortage discussed in this paper. The president, at the same time, argued the necessity of a more-balanced research and development attack on the energy problem and requested an increase in funds for the coal-gasification problem. Although this is a step in the right direction, it does not go far enough in anticipating the role of fossil fuel during the next 50 years in the U. S.

Some important factors were neglected, particularly the promise of MHD central power, both technologically and economically. The FY 72 proposed budget goes somewhat further in recommending increased expenditures for coal gasification and includes $3 million to begin an MHD central-power program. This $3-million amount is significant but inadequate when compared to the national programs conducted in other countries.

An Old Principle

Magnetohydrodynamic power generation is achieved when an easily ionized metal, such as potassium or cesium, is introduced into high-temperature combustion gas which is expanded to high velocity through a nozzle and then directed into a magnetic field with properly arranged electrodes and external circuit.

In this situation, a moving conductor cuts magnetic-field lines and a useful emf is generated. Although this kind of electrical configuration was described by Faraday over 100 years ago and was one of the first generator configurations invented, the problems associated with high temperature have prevented its application to combustion-gas plasmas until recently. Through the use of current high-temperature technology and some 10 years of research and development in MHD, the state of the art has reached the point such that 10 more years of work can produce large power plants in the 2000-MW range for practical use. The impetus for developing such plants lies in their high thermal efficiency, between 50 and 60 percent as compared to 40 percent for conventional fossil fuel and 32 percent for nuclear power plants. This makes MHD-type steam plants attractive from the standpoint of economics, thermal pollution, and air pollution.

Within the past two years a whole new technical situation has arisen within the context of a changing social climate, so that the current status of MHD is quite different from that set forth in the August, 1969, issue of Mechanical Engineering [5].[2] No longer is the future of MHD technology or any other tech-

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

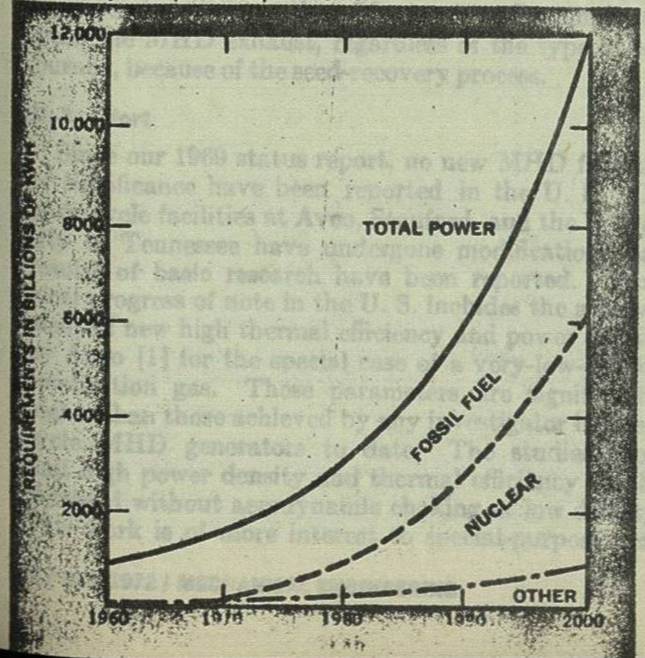
nology a simple estimate of technical feasibility and economic benefit. The public acceptance of power plants, the future power-demand curves, the cost of power-plant construction, and the effect of all these factors on power sources other than MHD must be considered in order to adequately describe the status of the technology. The posture of the federal government and its organization with respect to central power will profoundly affect the future of any technology and thus needs to be examined as well.

It is now, therefore, a good time to review the status of MHD central power. A good place to start is at the international meeting concerning MHD power generation held in Munich, Germany, in April, 1971. Of particular interest was the announcement of an operating Soviet MHD experimental facility, U-25. Extensive Soviet experiments on long-duration preheaters, MHD channels, and other components have been performed. Smaller, but significant, experiments on central power components have also been constructed in Japan.

Future of MHD

The prime question should be: Is the expenditure of some $282 million necessary to acquire MHD power-generation technology a reasonable technical risk in which the people of the U. S. can expect a large return in the future? If this question can be answered in the affirmative, then the discussion will turn to the acceptability of MHD power generation from the standpoint of safety to the public, pollution of the environment, and other peripheral economic effects to be reasonably expected. Fig. 1 shows a version of the traditional power-demand curve for the U. S. until the year 2000. It is possible to avoid answering questions concerning the competition between MHD fossil-fuel plants and a system of nuclear power plants by merely calling attention to the fact that nuclear plants by their very nature must be base-load plants and that the rest of the power needs might be satisfied largely by MHD power plants. Thus, some 30 percent of the power plants might be MHD plants with the rest nuclear. Such a power system is not necessarily the optimum one for the country, however. Leaving aside for a moment the question of the acceptance of the conventional nuclear plant and the breeders by the public, it is worthwhile to take a look at the economics of the nuclear system as compared to a system where fossil-fuel MHD plants take over a large portion of the power production.

Fig. 1 Projected power requirements.



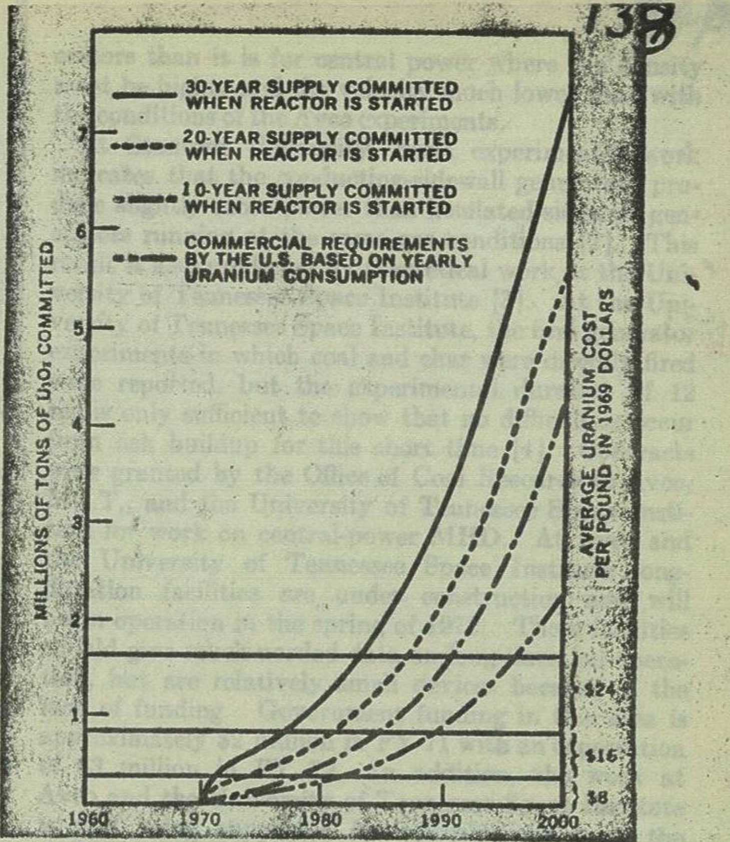


Fig. 2 Cumulative projected uranium requirements.

The lower curve in Fig. 2 shows the projected cost of uranium in 1969 dollars if nuclear reactors are put into service as estimated from the curve in Fig. 1. This is not a realistic cost curve because it assumes that uranium is bought at the time it is consumed, which is not the usual practice. If we assume that the utilities will follow the usual custom of obtaining contracts for nuclear fuel for all (30 years) or a large part of the lifetime of the reactors, our uranium reserve would be committed to fueling reactors as they are built. The effect is shown in Fig. 2 for 10, 20, and 30 years of uranium supply committed to the reactor when it is built. One sees that the reactors will be priced out of competition after 1985, because the 1969 price of $6.50/lb will have increased by a factor of three to four for new reactors. The standard answer from the nuclear establishment to all who point out this obvious future uranium shortage is that additional exploration will turn up the required uranium supply. However, anyone familiar with the current oil and gas situation will have grave reservations concerning the assumption that mineral resources can always be found when needed.

Another answer—this one from the Atomic Energy Commission—is that breeder reactors, when installed, will alleviate the uranium supply shortage. But even optimistic estimates of a fuel doubling time of 10 years in the breeder leads to a prediction that it would require 30 years to fully install a breeder system that

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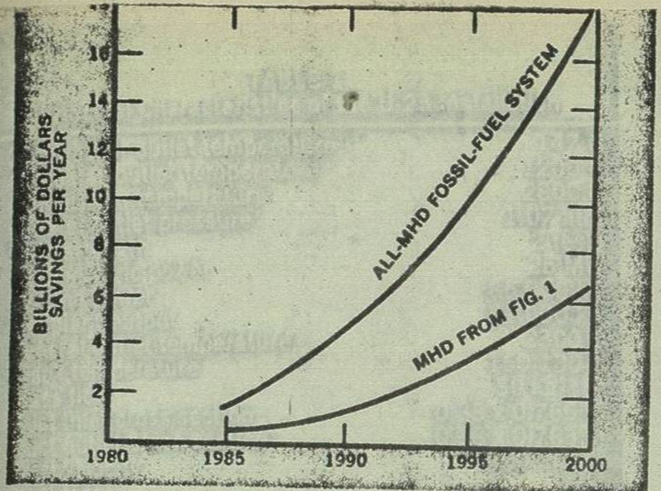

Fig. 3 Contrast between savings brought about by MHD from the fossil-fuel system predicted in Fig. 1 with an all-fossil-fuel system for plants constructed after 1985.

would supply most of the nation's power needs. One must add to this 30 years the fact that it will probably take at least 10 years to site and build the first generation of breeders and that the breeder, of course, is not developed as yet and may require 10 to 15 years development time. We finally come up with the fact that it will be 50 years from now before the breeder can fully supply the uranium required for a completely nuclear central power system in the U. S. It is obvious that breeder reactors will not be on the line in appreciable numbers before 1995, and that long before this time the cost of uranium will have risen by a factor of three or four.

Reduced Power Bill

The yearly savings in the nation's power bill, if MHD fossil-fuel plants were installed beginning in 1985 instead of ordinary fossil-fuel plants, are shown in Fig. 3. The upper curve represents the savings to be realized if fossil fuel takes over completely from nuclear fuel in 1985, and the lower curve indicates the savings if the split between nuclear and fossil-fuel power generation is as shown from the curves in Fig. 1. If MHD central power plants of 55 percent efficiency are developed, one would expect the savings in the power bill to lie somewhere between these two curves. The competition might very well be effective in lowering the cost of nuclear power as well. It is assumed in making these cost estimates that SO_2 is virtually eliminated from the MHD exhaust, regardless of the type of coal burned, because of the seed-recovery process.

U. S. Effort

Since our 1969 status report, no new MHD facilities of significance have been reported in the U. S. Old open-cycle facilities at Avco, Stanford, and the University of Tennessee have undergone modifications, and results of basic research have been reported. Technical progress of note in the U. S. includes the achievement of new high thermal efficiency and power density by Avco [1] for the special case of a very-low-density combustion gas. These parameters are significantly higher than those achieved by any investigator in open-cycle MHD generators to date. The studies show that high power density and thermal efficiency can be obtained without aerodynamic choking at low density. This work is of more interest to special-purpose generators than it is for central power where the density must be higher and the velocity much lower than with the conditions of the Avco experiments.

At Stanford University, basic experimental work indicates that the conducting-sidewall generators produce slightly more power than insulated-sidewall generators running at the same gas conditions [2]. This result is also predicted by theoretical work at the University of Tennessee Space Institute [3]. At the University of Tennessee Space Institute, the first generator experiments in which coal and char were directly fired were reported, but the experimental duration of 12 sec is only sufficient to show that no difficulties occur from ash buildup for this short time [4]. Contracts were granted by the Office of Coal Research to Avco, M.I.T., and the University of Tennessee Space Institute for work on central-power MHD. At Avco and the University of Tennessee Space Institute long-duration facilities are under construction and will begin operation in the spring of 1972. These facilities should give much-needed data on long-duration operation, but are relatively small devices because of the lack of funding. Government funding in this area is approximately $2 million in FY 71 with an expectation of $3 million in FY 72. In addition, the work at Avco and the University of Tennessee Space Institute is also being supported by contributions from the utilities.

International Status

By far the most spectacular results were announced by the delegation of the Soviet Union when it was stated that an announcement had been made in Moscow at the 24th Party Conference in March, 1971, that a new kind of power plant was in operation on the Moscow power network. This plant is the U-25 whose prospective design was described in MECHANICAL ENGINEERING's August, 1969, issue [5–8]. Conjecture in the U. S. had commonly speculated that this plant would begin operation somewhere around November, 1971, so it appears to be ahead of our original estimates. The plant is complete, except for the steam turbine of the bottoming unit which would be of no importance in the experimental plant. A new set of specifications for this plant was presented as shown in Table 1. The author and several other people from the U. S. had an opportunity to inspect this plant in conjunction with the Joint IAEA/ENEA International MHD Liaison Group meeting in Moscow in December of 1971.

The plant's exterior air preheaters consist presently of aluminum oxide, and are heated by natural gas and then used to heat the incoming air. Such heaters will be periodically cycled to provide a continuous flow of air at 1200 C. Such preheat is necessary in the MHD cycle in order to make the combustion products conducting. In the U-25 additional temperature is gained through the addition of a small amount of pure oxygen preheated at 1200 C to the air. The preheaters have been in operation for some time, though it is not completely clear for how long they have been operated. Others at the High Temperature Institute have been cycled for 8000 hr. Fig. 4 shows the MHD magnet enclosing the MHD channel and the accompanying diffuser. The combustion chamber is drastically smaller than the combustion chambers used with con-