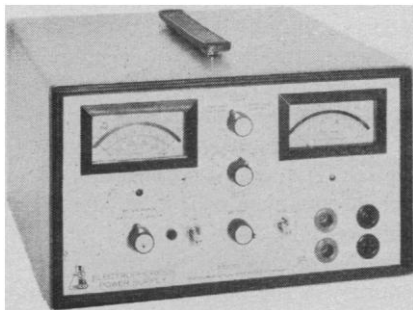


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LETTERS

The Future of Fusion

R. F. Post and F. L. Ribe (1 Nov. 1974, p. 397) offer an encouraging picture of the status of fusion research. I have little doubt that acceptable fusion reactors will come into being, but how large the required research and development effort must be, in time and in overall cost, is only somewhat less uncertain than it was a decade ago. I wonder, therefore, what guidance there is for those who plan the nation's energy program in statements such as "... in less than a decade sufficient scientific knowledge to ensure the practical achievement of fusion power will have been established."

Those of us who have lived through the development of fission reactor engineering recognize that the statement amounts only to a hope that the work of the next 10 years will not reveal insoluble problems. The real engineering task of scaling the power levels upward can then begin. We know that the upward steps cannot be too large, factors of 10 often being the upper limit. We know also that each such step requires 5 to 10 years and hundreds of millions of dollars to effect. This is discouraging from the point of view of a nation that is energy-hungry. The road from a few watts of fusion energy to units that can feed 500 megawatts into the electric energy grids is likely to be long and tortuous. Experience with nuclear power in the past three decades has demonstrated more than once how distant the practical, acceptable power systems can be from experimental laboratory successes. Engineering perspective has not been common among physicists on whom we depend for basic theoretical and laboratory demonstrations.

What should the nation's energy planners have gained from the article by Post and Ribe? That fusion research should be strongly supported is beyond question. It would be unfortunate, however, if "fusion enthusiasm" were to detract from substantially larger funding for the development of improved fission reactors and acceptable fission breeders. A carefully planned program for achieving the required national nuclear sophistication is also needed. Nor should the hope for fusion be permitted to detract from energy conserva-

tion efforts, from interim emphasis on coal products, or from the long-range benefits of solar resources.

It seems to me that the nation's planners are entitled to a better perspective on energy than the research community has been giving them.

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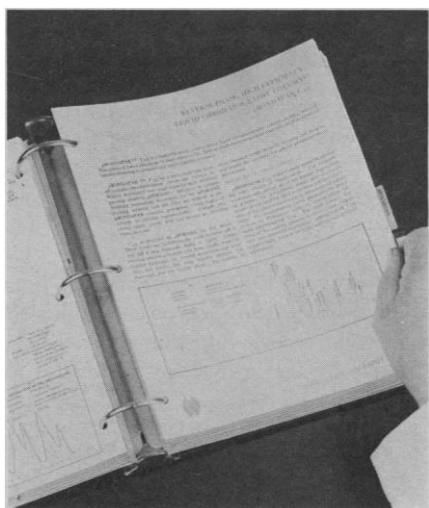
Post and Ribe make several points which we believe are seriously misleading. The most important of these is stated in the article as follows: "We propose that fusion should be considered as the ultimate source of energy, and that other sources of energy, including conventional nuclear power, should be considered as interim sources."

For those of us concerned with the development of *all* viable technical options for future energy development, such a statement is very controversial. It implies (i) that fusion is certain to be a proven energy source and (ii) that it will be available as a national option in a short enough period of time that nuclear fission power will be unnecessary. Both of these implications are manifestly in error. The present fusion energy program is primarily devoted to establishing the scientific feasibility of this process. Until that is done, it would be an enormous risk for both industrial nations and the world to consider fusion as a sure future energy option.

If we assume that the scientific programs now under way do establish in the laboratory that fusion can be successfully demonstrated as an energy source, it still remains a major development to assemble an engineering configuration that meets the end-use requirements of reliability and economics. The most optimistic projections for such a successful outcome indicate that it would be a minimum of 20 years before such a demonstration could be made and, more realistically, it is likely to take at least 30 years, even if success is met along every step of the way.

If one takes into account the time required for the integration into utility systems of a new commercial power source, the time interval from a first commercial demonstration to the manufacture and use of even a limited number of new power plants is at least 10 years and is usually longer. Thus the "interim" referred to in the article is clearly a minimum of 30 years under

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the most optimistic circumstances and, realistically, 40 or more years if we make the happy assumption that the fusion concept can meet scientific, engineering, and economic criteria. Such a time period can hardly be considered by any econometric or technical measures as an "interim" period.

In contrast, what is now considered conventional nuclear fission is producing electricity on a full-scale basis in operating electric utility systems and, in some cases, is responsible for more than one-third of the total energy production of such utility systems. Among those electric utilities that have both nuclear fission and fossil fuel plants, there seems to be a consensus that their choice for future expansion would be nuclear fission power. They base this choice on the economics, reliability, and continuously improving performance of nuclear plants. Nuclear fission power stations are a "here and now" commercial option.

The second principal point made by Post and Ribe is that "... the amount of induced radioactivity is to a considerable degree at the disposal of the plant designer in the fusion case, while it is an inherent property of the fuel in the fission case." This statement is technically correct. However, what is omitted is the corresponding statement that, in the case of fission, the release of radioactivity to the atmosphere and thus to the public is also under the control of the plant designer. Further, the engineering solutions in the case of fusion plants are still highly hypothetical, whereas the containment devices and the containment options in the case of nuclear fission plants are well developed and well known. The issue that remains in the case of our present nuclear power stations is the degree of containment in relation to economic investment. While we hope that the development of fusion concepts will permit the operation of fusion plants with a minimal amount of induced radioactivities (principally because this will improve their economic viability), we nevertheless have to recognize that the developments in this area are still at an exploratory level; we don't know what can, in fact, be achieved with the materials now known to man or with what might be available in the next 10 to 20 years. Figure 10 in the article by Post and Ribe illustrates this point, although the implications are not adequately reflected in the text.

The remainder of the article is a

review of magnetic fusion development, with the notable exception of laser fusion. The last paragraph appears to be a reply to our article (1) published in the *Journal of the British Nuclear Energy Society*, in which we attempted to present a balanced perspective of both fission and fusion and their potential roles. Although the quantitative analysis in our article could now be updated, we believe our general conclusions are still valid and overriding for long-range policy. It is our position that nuclear fission power plants as presently developed commercially and the development of fast breeder reactors are essential if we are to provide a viable supplement to fossil fuel resources in the next several generations. We also believe that energetic development of the fusion concept should proceed at as rapid a pace as the technology permits in order to provide another energy option. We recognize the potential advantages of fusion, but we are concerned that Post and Ribe tend to denigrate the need for fission power on the assumption that there is no uncertainty concerning the success of fusion. What do we do if the optimism about fusion turns out to be unjustified?

It has been pointed out that the fusion enthusiasts fear a success of the fast breeder reactor might possibly destroy future support for the fusion program. It is true that a successful fast breeder reactor will, from a resource point of view, reduce the need for a successful fusion power plant. However, the very differences and advantages fusion might have in terms of its overall environmental and social implications would make it desirable as an option. We deeply regret the apparent implication that, for the fusion program to maintain its financial support, it is necessary to undermine support for conventional nuclear power and the fast breeder reactor. Both concepts need to be pursued with enthusiasm and support.

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1. C. Starr and W. Häfele, *J. Brit. Nucl. Energy Soc.* 13, 131 (1974).

We appreciate the comments by Parsegian and by Starr and Häfele as additional contributions to finding the wisest path to meeting man's future needs for energy. While they agree that fusion is an extremely desirable future energy source and should be pursued vigorously, there are areas of concern in both letters which we should address. As we interpret their comments, they could be paraphrased briefly as follows: "Since fusion power is as yet unproved, is it not possible that we underestimate the time and effort needed to achieve it and thus are being premature in proposing now that fusion power development should occupy a special place in energy planning, relative to presently existing sources—particularly nuclear fission?"

As we mentioned in our article, in the absence of working fusion reactors the position we advocate necessarily involves uncertainties. These we recognize and accept. Nevertheless what we are asking for in essence is a commitment to the future—a commitment that recognizes that we desperately need future energy sources that are more than simply practical and economical. They must at the same time satisfy considerations of minimal environmental impact and of safety in its broadest sense—both physical and political. In the future these latter issues may well come to dominate. Is it not possible that, in the future, society might place a premium on those energy sources which enhance its own safety and political security? As we indicated, during an interim period—the length of which we did not estimate—present-day energy sources, including nuclear fission, will have their day. What we espouse is a national frame of mind that will take *all* factors into account in pursuing energy research and development. In this spirit we would have to accept the possibility that fusion, too, might in time be augmented or even displaced by some still more desirable ultimate energy source. What we have asserted is that fusion could take on the task of satisfying man's energy needs for the future and that it could evolve toward an increasingly safe and environmentally attractive system. Figures 10, 11, and 12 in our article give some comparisons that illustrate the point, including the fact that the fusion reactor designer should have options for reducing the hazard potential that are a priori not open to the fission reactor designer.

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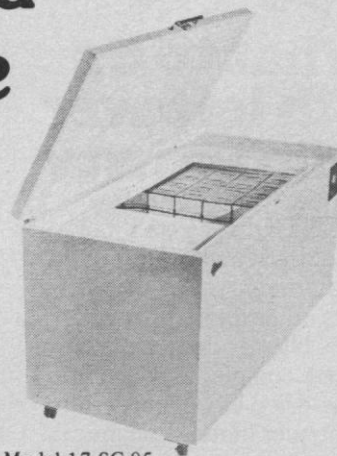
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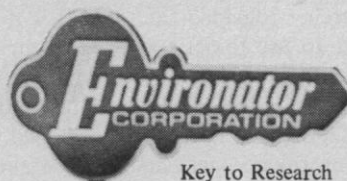
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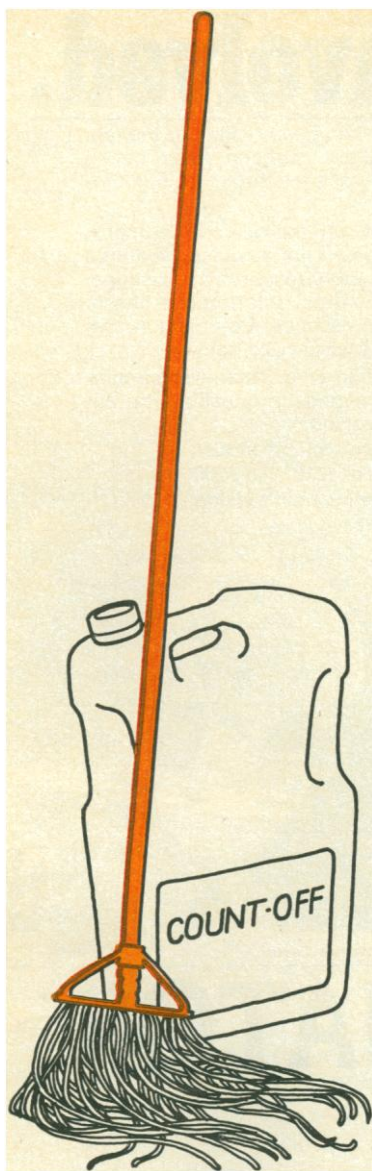


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argues against research and development of other energy sources—including fission. What we do argue against is a national policy that would require that fission power—or anything else—must precede and thereby delay or exclude the inception of fusion.

In our democratic society, decisions are ideally arrived at by integrating the input from all sources. We therefore agree with Parsegian on the need for the broadest input possible to what we all feel is perhaps the most critical technical-political issue that we in this century have been asked to resolve—from whence will come the energy to build a better future world?

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Thioctic Acid and Mushroom Poisoning

In Barbara J. Culliton's article "The destroying angel: A story of a search for an antidote" (*News and Comment*, 16 Aug. 1974, p. 600), Frederic C. Bartter, clinical director of the National Heart and Lung Institute at the National Institutes of Health, refers to experiments performed at the Food and Drug Administration (FDA) in which thioctic acid and glucose cured mushroom poisoning in dogs. As the unnamed researcher who conducted the experiments and analyzed the data, I wish to point out that my findings are reversed in Culliton's report. Bartter is quoted as saying, "So, in the later experiments we carefully maintained glucose levels in the dogs, just as you routinely would in a patient." In fact, I found that the low blood glucose levels in mushroom-poisoned dogs were *not* restored to normal by six hourly injections of dextrose and thioctic acid. Culliton continues, "It appears that this was the problem. When dogs receiving toxin and antidote were also given glucose, they survived. The researchers decided then that it is reasonable to use thioctic acid experimentally to try to save the lives of victims of the destroying angel." In fact, I found that four of five mushroom-poisoned dogs given thioctic acid and glucose and five of five mushroom-poisoned control dogs

died. I reported this finding to my FDA colleagues, including Alan K. Done, who, as Culliton indicates, communicated with Bartter. Culliton's article suggests that there is renewed hope for victims of mushroom poisoning and appears to encourage doctors to request emergency shipments of thioctic acid antidote. Unfortunately, the negative results I obtained with thioctic acid in both mice and dogs do not justify this hope or course of action.

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As Culliton reported, I was asked to assume the IND (investigational new drug) application for thioctic acid on the basis of numerous more or less favorable reports of its clinical use from Europe, and a few from the United States.

I did indeed discuss with Alan Done experiments designed to test its efficacy in animals. He showed me reports of mouse studies which did not show a therapeutic effect for thioctic acid given in distilled water. We agreed that no test of the effectiveness of thioctic acid in which blood sugar was not maintained could be of value. This is because both amanitin poisoning and thioctic acid may produce hypoglycemia.

I wish to emphasize that I had no part in the design of the experiments which were then done on dogs. I was simply informed later (August 1974) by the Food and Drug Administration (FDA) that it was reasonable to proceed with the IND.

Recently (December 1974), I received the details of the dog studies. From them one may infer the reasons the FDA decided to proceed from the clinical evidence not to withhold thioctic acid from human subjects poisoned with amanitin. It was clear that dog studies designed as these were had done nothing to clarify the issue. Glucose had been given in tiny doses of 500 milligrams by six hourly injections (3 grams a day). Of course the dogs that died (four out of five) showed hypoglycemia. In human subjects, thioctic acid should be given with a sustained intravenous drip of glucose, and the total dose of glucose should be at least 100 grams a day. With this regimen, no human subject has been reported to show hypoglycemia.

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