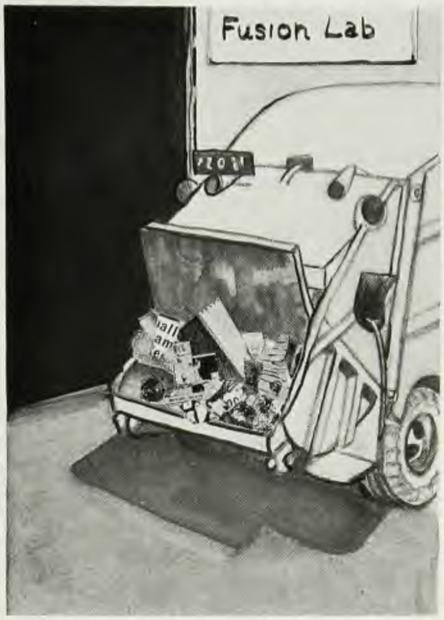
letters

In defense of the fusion torch

In your February issue (page 32) the article "Physics Looks at Waste Management" by David J. Rose, John H. Gibbons, and William Fulkerson comments on the "fusion-torch concept." However, the article does not accurately represent our ideas as presented in published papers.[1-9]

The purpose of proposing the "fusion-torch concept" in 1968 was to stimulate interest in the use of the science and technology that had been developed under the fusion-power program to meet both the near and long-term needs of society. As the term is used today, the fusion torch refers to the class of devices that can be powered either by electrical energy (source torch) or energy contained in a fusion plasma (reactor torch). For both kinds of torches the energy content of the plasma can be transferred to the material to be processed by either electromagnetic radiation or particle kinetic energy.

The fusion-torch concept has successfully stimulated physics research and studies. The original ideas have been extended and expanded due to the talents and efforts of many individuals. Source-torch applications for the production of ultraviolet radiation have been studied by Farrington Daniels of the University of Wisconsin and by Fusion Systems Corporation, Rockville, Maryland. Boeing Research Laboratory, Seattle, Washington, is studying the development of a source torch for the reduction and separation of aluminum ore and other applications. Individuals who have worked on source-torch applications are W. R. Powel of Johns Hopkins Applied Physics laboratory in Baltimore, Maryland; S. Mitro, M. O. Hagler and M. Kristenson, Texas Tech University; Frank Edlin of Arizona State University; Zeinab Sabri of the University of Wisconsin. Reactor-torch studies have been carried out by Zeinab Sabri, and by W. A. Porter, M. O. Hagler, and M. Kristenson of Texas Tech.



Rose *et al* have raised objections to the use of a fusion reactor torch for the processing of material. They quote an ORNL report as showing the total coal equivalent energy to mine, beneficiate and electrolytically refine a ton of aluminum to be 56 000 kWh (60 eV/atom of finished aluminum), and imply that this is an extreme example. However, this same reference indicates that the total coal equivalent energy to refine titanium is 134 077 kWh per ton or 268 eV/atom of finished titanium. In fact, just to recycle scrap titanium metal, the ORNL report gives a figure of 39 000 kWh of equivalent coal energy per ton, or 78.6 eV/atom. Thus the statement by Rose *et al* that, "in general," recycling energies are in the 1–10 eV range is not accurate. Recycle energies may be this low for such easily worked scrap components as aluminum cans, and separated scrap iron; however, techniques have not as yet been developed for recycling the really difficult complex of mixed metal, carbon and other elements that result from advanced incineration techniques. In view of their energy requirements, it is hard to see why the 30–40 eV estimated by Rose *et al* for ionization of atoms in the fusion torch presents an *a priori* reason for calling the concept unrealistic. Furthermore, the energy required for ionization of solids in plasmas does not have to include the large excitation loss mentioned in the Rose *et al* article. For example, if ionization occurs in an optically thick plasma, then the excitation photons are not lost from the plasma-solid system, and thus are reabsorbed in the ionizing system. The energy requirements for ionization are therefore much closer to the ionization energies of the elements (3.85 eV to 24 eV).

A more important factor influencing the energy use in the "fusion-torch concept" is the separation technique used.[2,7] Many possibilities exist besides the electromagnetic isotope-separation techniques developed at ORNL, which incidentally need not be so costly when used to separate elements. Techniques that have been suggested include (1) electromagnetic, (2) quadrupole magnets, (3) plasma centrifuge, (4) plasma acceleration, (5) inertial effects, (6) selective recombination, (7) charge exchange, (8) use of plasma resonances, (9) MHD effects and (10) quick-quenching. These could all be used with the source torch but techniques (1), (3) and (4) would probably be the best for the reactor torch.

The handling of wastes represents an extension of the technology required for ore processing. Common sense would dictate that, where economically appropriate, presentation of material such as iron be carried out before processing via a fusion torch (either source or reactor torch). Thus we find the qualitative sketch given in figure 4 of the Rose *et al* article to be gross distortion of both the "fusion-torch concept" and its wide range of possible energy requirements.

The objections by Rose *et al* appear to come from the viewpoint that fusion energy should be harnessed merely to produce electricity. Our viewpoint of the fusion reactor torch is different. We believe that the extraction and use of energy in other forms is possible and that systems should be designed and optimized for such purposes.

Although the various fusion-torch possibilities are largely untested and aspects may turn out to be impractical, the "fusion-torch concept" itself appears to be viable. The ingenuity of physicists, chemists and engineers is

proving this to be so. The needs for this technology exist, the challenge is there, and we predict it will be met.

References

1. B. J. Eastlund, W. C. Gough, Bull. Am. Phys. Soc. **11**, no. 13, 1564 (November 1968).
2. B. J. Eastlund, W. C. Gough, "The Fusion Torch—Closing the Cycle from Use to Reuse," WASH-1132 (15 May 1969).
3. B. J. Eastlund, W. C. Gough, "The Fusion Torch—Unique Applications of Ultra-High Temperature Plasmas," Proceedings of the Conference on Nuclear Fusion Reactors, Culham, UK (17–19 September 1969).
4. B. J. Eastlund, W. C. Gough, "The Fusion Torch—A New Approach to Pollution and Energy Usage," AICE Chemical Engineering Progress Symposium Series **66**, no. 104 (1970).
5. W. C. Gough, "Why Fusion?", WASH-1165 (June 1970).
6. B. J. Eastlund, "Pollution Control is Elementary—with Fusion Plasmas," *Water and Pollution Control* (January 1971).
7. W. C. Gough, B. J. Eastlund, "The Prospects of Fusion Power," *Scientific American* (February 1971).
8. W. C. Gough, B. J. Eastlund, "Energy, Wastes, and the Fusion Torch," paper presented at the AMA 8th Congress on Environmental Health, New York (26–27 April 1971).
9. W. C. Gough, "Possibility of Fusion Reactors as Radioactive Waste Burners," a compilation of material for the CTR Technology Group, (13 July 1971).

BERNARD J. EASTLUND
WILLIAM C. GOUGH
Atomic Energy Commission
Washington, D. C.

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The authors' humorous analysis of the concept led ultimately to a predetermined conclusion: that is, "the fusion torch is a fundamentally poor idea," "will not work," and "will not be practical." Obviously their discussion of the torch concept showed complete unawareness of a few facts:

▶ Plasma torches, *per se,* are in current use on an industrial scale, and in experimental studies of plasma chemistry. They were largely developed by NASA in the last two decades.

▶ The bulk of literature available on plasma torches (or plasma jets) dates back to the 1950's.

▶ The fusion-torch concept, which was recently put forward by Eastlund and Gough, is suggested primarily as a means by which the industry may exploit the range of plasma temperatures and densities that has already been explored in the fusion research program. The concept is a novel approach to overcome the deficiency of present-day torches. Its realization would be a breakthrough in plasma-torch technology with regard to productivity and efficiency.

▶ A prototype fusion torch could be realized at the present time, with available torch technology and laboratory plasma experience. In fact, the concept is already demonstrated partially by high-current injection experiments and by rotating plasma separation.

▶ Feeding the torch with hot plasma from the exhaust of a fusion reactor is proposed as a means of plasma energy utilization if it is to be otherwise wasted, or if there is no competitive technique other than thermal conversion to convert this energy to electricity. The fate of the torch does not depend in any way on the fate, the shape, or the exhaust of fusion reactors.

▶ Waste processing by the torch can be done without any need for a medium of hydrogen isotopes.

▶ The fusion torch is neither a mixer, as is being implied in the article, nor a "blowtorch" of the "primeval" type familiar to the authors. It is rather an efficient separator.

▶ A simple, back-of-the-envelope calculation shows that in case of a complete failure of the separator in a fusion torch, the tritium concentration in iron, for example, at the torch output does not exceed 0.046 ppm. In normal operation, this ratio is reduced below 0.001 ppm without any special separation scheme.

▶ Waste processing in the torch does not require full ionization of the atoms. It is sufficient to ionize a fraction of the injected material to achieve separation. Thus, an aluminum atom "will carry on its back" about 6 eV rather than the few hundred suggested.

▶ Future shortages of basic elements will definitely offset the price scale, especially when low-grade resources are used.

▶ Collection rates and efficiencies in a plasma separator can exceed those of electromagnetic and chemical separators. This is a fact that was demonstrated experimentally.[1] Thus, even if the high prices quoted in the article are correct, there is room for recovering material in usable form at relatively low cost.

In their proposal, Gough and Eastlund[2] left room for the ingenuity of the physicist and engineer to implement the concept in a way that guarantees optimum energy utilization with maximum economical benefit.

Reading the article with these facts at hand is enough to refute the fallacies used to condemn the new technology. Making big decisions as to the fate of innovations and new ideas with hand-waving arguments and without doing the necessary investigation is not a constructive attitude.

A scholar, teacher and friend once said, "Do not condemn a new technology because it *may* become important and hence economical." The authors based their scheme of waste management on the "cow" philosophy of taking the minimum energy path. The "cow" does not think in terms of dollars as we do. If the maximum energy path produces a product with higher dollar value we will certainly follow it. I wonder if humanity chose to move horizontally, what would have happened to our civilization? I guess we could have been creeping still in the cow age (stone age!).

References

1. B. Bonnevier, "Experimental Evidence of Element and Isotope Separation In a Rotating Plasma," Report No. 70-8, Division of Plasma Physics, Royal Institute of Technology, Stockholm, Sweden (1970).
2. B. Eastlund, William Gough, "The Fusion Torch, Closing the Cycle from Use to Reuse," WASH-1132 (1969).

ZEINAB A. SABRI
University of Wisconsin
Madison, Wisconsin

AN AUTHOR COMMENTS: Our criticism of the fusion torch was quite specific and related to what has appeared or been implied in a number of public and semipublic pronouncements, to wit: a materials reprocessing system ties on to a controlled nuclear fusion reactor, and using the raw output of escaping plasma to do the work. That is what has commonly been understood as the fusion torch.

Actually we have little substantial quarrel with Eastlund and Gough, who intend the term to cover a whole range of plasma processing phenomena not connected with controlled fusion, but utilizing advanced ultrahigh-temperature plasma techniques. Those are different things—aluminum-ore reduction, CF_4 production, and so on—and utilize specifically nonfusion plasmas much more suited to the purpose. We applaud rational development of such technology, and had no intention of criticizing it.

Thus the difficulty seems to be semantic and reminds me of a small company that once existed not far from MIT, which was called Stellar Expansion, Inc—once you realized that they manufactured expansion bits, the term of reference became simplified.

Many of the same comments could apply to the letter by Sabri, but we do not agree with some of his "back of the envelope" calculations. He makes the point that separation requires only a weakly ionized plasma at fairly high pressure; these conditions are quite inconsistent with nuclear fusion itself. We assure him that we are aware of the main concepts of these things. A small collection of analyzed articles presently at hand weighs two pounds.

DAVID J. ROSE
Massachusetts Institute of Technology

Can children aid physicists?

The searching article by Jean Piaget on children's views of the world (June, page 23) points up a general principle I have seen at work both in my own children and in my recollection of my evolving views from childhood onward—a principle that I would tentatively express by the two propositions:

- If something is important, it is simple.
- Simplicity is the most difficult thing to achieve.

This, of course, agrees with Piaget's findings that the child begins with the "undifferentiated" (complex) concept, and is led eventually to the "differentiated" (simple) concept.

From this viewpoint I would conclude, now possibly at variance with Piaget, that the only interest a physicist could have in a child's view of the physical world would be either historical or pedagogical, but that he could not possibly be inspired professionally, except through sheer accident, by a child's view of the physical world. Indeed, there is, for instance, an enormous gap between the child's concept of action and Maupertuis's.

This is all to say that physics forms part and parcel of civilization and constitutes the beautiful inherited artifact carved out of observations by the great simplificators of the past.

MARCEL J. E. GOLAY
Clair-Azur
Switzerland

THE AUTHOR COMMENTS: Marcel Golay has not understood the intention of my article. It goes without saying that I do not suppose that psychogenetic results can "inspire" the physicist in terms of his professional work. On the contrary these results contribute to the analytic work of *physical epistemology* and for this reason have caught the interest of famous physicists such as Einstein, Oppenheimer, and de Broglie and have motivated physicists such as Louis Rosenfeld and Jean-Marie Souriau to collaborate with our efforts.

JEAN PIAGET
University of Geneva
Geneva, Switzerland

Help for hurricane victim

The physics department at Wilkes College is located in The Stark Hall of Science, which is only 500 feet away from the banks of the usually sleepy Susquehanna River, which on 23 June rose to over 40 feet in wake of the rain