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THE FUSION TORCH

Closing the Cycle from Use to Reuse

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Division of Research
United States Atomic Energy Commission

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by

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ACKNOWLEDGEMENT

The concepts expressed in this paper evolved from the strong belief on the part of the authors that controlled fusion should not be viewed solely as another means of providing heat to generate electricity via the conventional steam turbine cycle. Rather controlled fusion should be investigated as a new *prime energy source* with potential inherent advantages uniquely suited for direct conversion of energy into forms useful for society. We believe the fusion torch concept to be one such important advantage obtainable from fusion energy.

For this concept to reach its present stage required the contributions of many persons. We would like to take this opportunity to acknowledge these contributions.

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SYNOPSIS OF THE FUSION TORCH CONCEPT

Bernard J. Eastlund and William C. Gough

Two concepts for the application of the ultra-high temperature plasmas now available in fusion experiments and eventually in controlled fusion reactors will be discussed. The first concept is the use of ultra-high temperature plasma, in the form of a fusion torch, to reduce *any* material to its basic elements for separation. The second concept is the use of the fusion torch to transform the energy in the ultra-high temperature plasma into a radiation field, to permit process heating to be done *in the body* of a fluid.

The basic concept of the fusion torch assumes that a plasma is transferred from the region where it is generated through a connecting region which isolates it from the plasma source to an interaction region. In the interaction region the pure ultra-high temperature plasma is ready for fusion torch applications.

The first application is the use of the fusion torch to reduce materials to their basic elements. For control of operations, plasma temperature and flow velocity in the interaction region can be regulated by expansion and contraction of the confining magnetic field. The ability to do this can be shown from the plasma's energy conservation equation. The high thermal conductivity and large energy flux of the fusion torch plasma leads to shock vaporization and ionization of a solid rather than ablative cooling (as occurs in a low temperature arc plasma). The result is that plasma energy is transferred to the solid on a time scale characteristic of the residence time of the solid in the fusion torch and without excessive impurity radiation losses. Analysis of laser produced plasma supports this contention although an experimental verification is needed. The status of plasma technology permits such an experiment to be carried out now.

The plasma, composed of ionic species of the solid, proceeds into a separation region where a variety of techniques can be used to segregate the ionic species according to either atomic number or atomic mass. Possible separation techniques include (a) electromagnetic, (b) quenching the plasma flow stream, (c) selective recombination, or (d) charge exchange. Using *energy consuming* ultra-high temperature plasmas, limited applications may be practical now for ore reduction or certain scrap recovery. When fusion reactors are available, volume of materials equal to thousands of tons per day could be handled in a single plant. The handling of urban wastes then becomes a possibility. Thus the ultimate goal of closing the material's cycle from use to reuse could be achieved.

The second application of the fusion torch is to transform ultra-high temperature plasma energy into a radiation field by injecting trace amounts of selected materials into the torch. The emission frequency and intensity of the emitted radiation can be controlled by varying the amount and type of material injected into the plasma. It is possible to maximize the energy in chosen narrow spectral bands. This can be shown from the time dependent coronal equilibrium model which is valid for fusion plasma conditions (this would not be the case for a plasma arc).

The radiation can be generated in the ultraviolet (or another range if desired), transmitted through a window material, and absorbed in a bulk working fluid. The present limitation on bulk processing established by surface heat transfer has been removed. For fusion reactors, the intermediate step of conversion from a prime energy source to electricity has likewise been eliminated.

A flux of ultraviolet energy as high as megawatts per square meter could be obtained if desired. The absorption coefficient for ultraviolet radiation in the window has been demonstrated to be very low for special synthetic quartz. Based upon recent work on radiation resistant window material, suitable window material could be developed even for the highest fluxes. The window material need not be in physical contact with the fluid since the fusion torch could be used much like a heat lamp to illuminate a large area of material.

The absorption depth of ultraviolet radiation in water is about one meter, thus permitting bulk heating. The ultraviolet energy could be applied to any of the current uses of such energy, for example sterilization and photolysis. With the availability of fusion power, large volume applications such as desalination of water, processing of urban sewage, plasma chemistry and the conversion to electricity through fuel cells become possible.

There is an immediacy to the problems capable of solution by the fusion torch and hence by fusion power which warrants serious attention to the concept. The world is now on the steep slope of a rapidly rising transient driven by a population explosion. Over the next 30 years, there appears little probability that the world population can be significantly reduced below the projected seven billion persons for the year 2000. The result will be extraordinary demands for food and raw material accompanied by growing volumes of wastes and pollutants.

Unprecedented amounts of auxiliary energy will be required to amplify the amount of the sun's energy that can be harnessed by civilization. This amplification is essential if large urban populations are to live in an industrialized society and a habitable environment. The choice of energy sources will be limited. Usable for a short term are fossil fuels and fission water reactors, for the longer terms we must depend upon three potential sources of energy: (1) conversion of the sun's energy, (2) fission breeder reactors, or (3) controlled fusion energy. All other energy sources such as water power are insignificant for meeting the world's future energy requirements. Each major energy source has unresolved questions that may limit its availability or make the choice of an alternate desirable. Such questions as the effect of CO_2 buildup and other pollutants upon the atmosphere, the limitations enforced by thermal effects, the safety of the system, the buildup and storage of radioactive wastes in the environment, the proliferation of nuclear materials, and the economic, technological and scientific feasibility of the energy sources could make the *option* of an alternate energy source crucial to the preservation of an industrialized civilization.

Research aimed at controlling fusion energy has been making significant advances. Fusion power offers many advantages as an energy source. Its fuel is inexpensive, widely available, and virtually inexhaustible. It is inherently safe against nuclear explosion. It releases no combustion products to the air and its reaction products are non-radioactive. It has the potential of operating at very high efficiencies and thereby greatly reducing thermal pollution.

Over 5 years ago, controlled fusion research achieved its first goal of heating a dilute gas of fusion fuel to temperatures of hundreds of millions of degrees. Such ultra-high temperature plasmas are now routinely produced. These plasmas could be applied to present day industrial needs. By taking full advantage of the unique properties of fusion plasmas that will be available from future controlled thermonuclear energy sources, solution to pressing problems in the United States will be possible.

Three areas are becoming of serious concern in the United States—the disposal of solid wastes, the availability of fresh water, and adequate supplies of raw materials. Over the 35 year period from 1965-2000, almost 10 billion tons of solid refuse will have been accumulated in the United States. If compacted and buried to a depth of 20 feet, a land area the size of the State of Rhode Island would be required. Water shortages exist now in certain parts of the United States and are projected to grow worse. Ground-water supplies are already overdrawn in the Southwest. Large water desalting plants have been proposed as a possible solution. The United States is today a have-not nation where raw materials are concerned. Of the 100 minerals most important to its industries, the United States possesses within its national boundaries adequate supplies of only about a dozen.

The fusion torch concept offers the ability to meet the urgent future needs for raw materials including water and to eliminate the buildup of wastes. Thus, the fusion torch concept offers the potential for the immediate application of ultra-high temperature plasma and can add impetus for the development of fusion power.

TABLE OF CONTENTS

THE FUSION TORCH – CLOSING THE CYCLE FROM USE TO REUSE