FUSION AS POWER

James Coogan

JAN 1988

ABSTRACT: Although the USSR built commercial fusion reactors (TOKAMAK) in the 1980s, scientists have since determined that engineering constraints prevent development of more efficient and profitable reactors. Despite failures in fusion research, however, scientists continue to seek a way to develop successful models to tap into fusion's potential for creating large quantities of energy. Possible applications include: civilian energy production, processing or destruction of radioactive materials, radioisotope production, as an X-Ray source for physics research, space exploration (in the form of a fusion micro-explosion and resulting fusion pellets). Proof of the scientific feasibility for the application of the fusion reaction will ultimately lead to concrete results.

PUBLISHED:

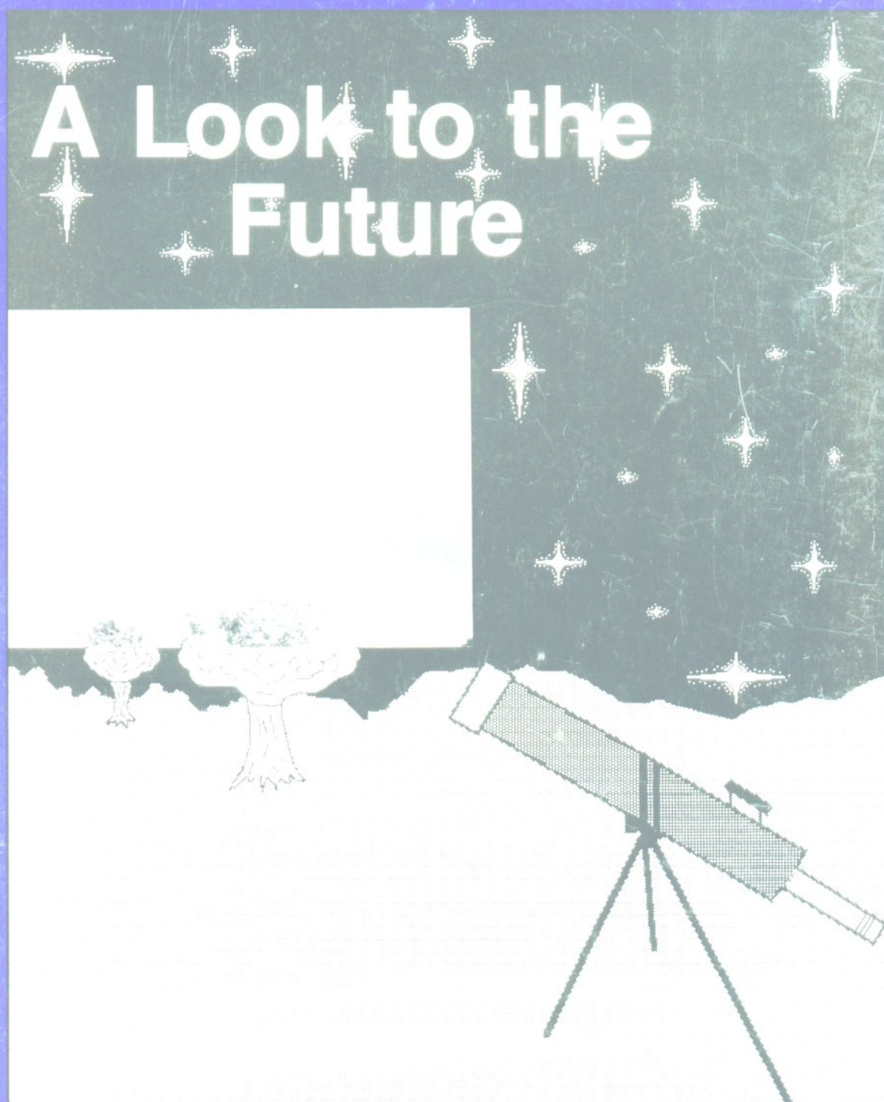
"University of Notre Dame Technical Review"
WINTER 1988, Volume 40, Number 2, pp. 6-7, 10.

ISSN: 0029-4543

UNIVERSITY OF NOTRE DAME

TECHNICAL REVIEW

WINTER 1988



UNIVERSITY OF NOTRE DAME

TECHNICAL REVIEW

WINTER 1988 VOLUME 40 NO. 2

Cover design by Eric Fick with a special thanks to Patrick Fischer.

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The NOTRE DAME TECHNICAL REVIEW (ISSN-0029-4543) is an official publication of the University of Notre Dame, Notre Dame, IN 46556, published quarterly, Spring, Summer, Fall and Winter and edited by the undergraduate students of the College of Engineering. Subscription price is $12.00 per year; single copies $3.00. All correspondence should be addressed to the Editor, NOTRE DAME TECHNICAL REVIEW, Engineering Building, Notre Dame, IN 46556. Publisher's representative: Littell-Murray-Barnhill, Inc., 1328 Broadway, New York, New York 10001, and 221 No. LaSalle St., Chicago, Ill. 60601. Member of Engineering College Magazines Associated. Entered as second class matter at Notre Dame, IN.

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by James Coogan

In 1939, just one year after the discovery of fission, U.S. physicist Hans Bethe recognized fusion as the energy source for the sun and stars. Further research revealed that such a nuclear reaction occurs when two or more relatively light atomic nuclei combine to form a heavier atomic nucleus. Fusion was also determined to release substantial amounts of heat energy when elements such as hydrogen were involved. The amazing potential for fusion power was demonstrated conclusively in 1953 with the detonation of the first H-Bomb.[1]

Apart from this display, however, progress in the field of fusion development was limited to theory for most of the next twenty-five years. Still, the knowledge of plasma physics collected in those years helped provide a base for concrete results in the form of STARFIRE, a study of ideal commercial fusion reactor prospects, and Soviet tokamak reactors in 1980.[2]

DESIGNS FOR THE FUTURE

In the years since the first fusion reactor was built, research and supplementary analyzation of the existing systems has led to a wide variety of new designs for future construction. Most of the advances and improvements are based on increasing knowledge of the nature of plasma, the high temperature mixture of free electrons and bare atomic nuclei. This acts as a fuel for thermonuclear reactors. Plasma engineers have formulated designs for innovative traps to force plasma to react. One of these, the magnetic trap, is already employed in tokamak reactors while a more advanced mirror trap is still under consideration.[3]

While the technology of most fusion reactor designs is considered correct by physicists and engineers, most have not been scientifically proven to work. This has led to many changes in single models and the conception of the wide variety of promising reactor types below:

TOKAMAK: A commercial fusion reactor using magnetical traps and emphasizing high beta production based on higher fusion core power density and reduced engineering volume. Low power tokamaks can be built with low financial risk as modules of a larger multiplex station.[4] The level of beta in a tokamak may be increased with adjustments to the current density of the plasma. This is the most basic and oldest fusion reactor design.[5]

STELLARATOR: A more advanced reactor type which utilizes an advanced torus facility (fuel center). It operates with a currentless plasma, requires infrequent shutdown, and boasts a startup with limited delay.[6] Operation of the system is disruption free and, like TOKAMAK, is most economical when part of a multiplex power center.[7]

TORSATRON: A reactor type only different from STELLARATOR in that the system is more compact. This model also uses currentless plasma for generation of power.[8]

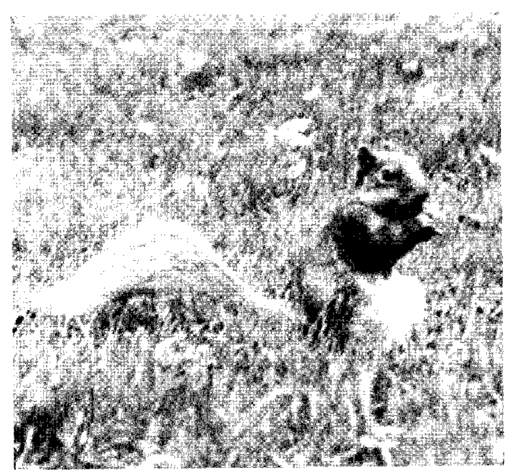
MINIMARS: The most advanced design yet presented. It incorporates existing hardware (turbine generators, electron cyclotron resonance heaters, and free electron masers) and emphasizes passively safe operation. Waste disposal for the reactor is class C (or better) and factory-built components along with multiplex capability add to its potential. The system is designed to provide the lowest possible cost of electricity and to utilize maximum possible mass.[9]

TURBOSTAR: An inertially confined fusion reactor which combines thermal and direct power conversion to obtain high-power efficiency. It possesses a design similar that of TOKAMA.[10]

FUTURE SYSTEMS RESEARCH

Although the physics principles for fusion are well established, engineering constraints have delayed execution of most reactor designs. Further, analyzation of existing tokamak reactors has revealed previously unnoticed design drawbacks. The future success of the construction and proliferation of fusion reactors, therefore, hinges on the resolution of present deficiencies of design.

Reactors utilizing very high beta have been shown (theoretically) to generate power at costs less expensive than existing nuclear facilities. And, since the torus structure and current drive significantly affect the beta level in tokamaks, they have been objects of leading importance in variations of present designs.[11] Advanced models of the tokamak possess a spherical torus and fast wave current drive and provide levels of power comparable to those of STARFIRE, the ideal tokamak design.[12] Meanwhile, new and simpler tandem mirror designs have been proposed to enhance reactors such as MINIMARS and to lower the present cost of energy production by the system.[13]



Almost as important, the systems complementing the torus structure and current drive (such as the first wall, breeding blanket design, and plasma current confinement) are being reviewed and redesigned to improve the total reactor design.[14] Engineers are also focusing on the maintenance and impurity control techniques, such as the containment of dust and tritium during shutdown, which have created unnecessary problems with design and have hindered the reliable operation of fusion reactors in the past.[15]

FUTURE APPLICATIONS

Once design problems are alleviated, fusion energy will be able to effectively replace both conventional electric and nuclear fission reactors as the world's power sources. Along with the improvements, the most efficient fusion facilities of the future will be in the form of multiplex reactor setups. The benefits of such a system would include increased use of shop fabrications, decreased site construction time, and higher overall plant availability. Also, the standardization and inspection of units would be much easier under such a system.[16] The use of multiplex systems would be economical because of shared equipment costs and reduced maintenance time due to the modular separation of operative from inoperative units.[17]

With its incredible power-generating capacity, the fusion reactor could easily become a substitute for existing electrical and fossil fuel energy facilities. While the tokamak and MINIMARS reactors effectively distribute electrical power, the HYFIRE (modified tokamak reactor with an integrated high-temperature hydrogen electrolysis device) should be capable of generating Synfuel to replace known fossil fuels.[18]

Fusion could also offset the influence of the fission and thermal reactors in the energy community because of its potential to produce fissile fuel, dispose of fissile waste, and generate process heat. TURBOSTAR was designed to produce tritium commercially using the principles of inertially confined fusion.[19] Other future reactors will be capable of using Beryllium to produce fissile fuel in higher quantities than existing breeder reactors. Still others will "burn" harmfully radioactive waste by recombining decayed particles.[20] All fusion systems will be a part of the production of process heat and may be combined with a heat transport system to supply much needed thermal energy to industrial production.[21]

Apart from the potential prominence of fusion reactors in commercial energy production, fusion technology will also expand the range of possibilities for scientific studies. The space program and Strategic Defense Initiative, primarily, have been developing designs for fusion-powered components which will greatly reduce required amounts of time and money. One of the leading examples in the area of space travel is the fusion microexplosion theory. Magnetic thrust produced by exhaust plasma mixed with additional propellent, the velocity of a fusion spacecraft, powered by fusion pellets would exceed the maximum speed of all other known fuels.[22] Simple fusion reactions will also give SDI the capability of simulating the environment resulting from the detonation of a nuclear device and the effects of a nuclear power source on a space platform without actual, costly testing.[23] Other future applications of fusion include radioisotope production, radiation processing, and X-Ray sources for physics research.[24]

The progress in the understanding of plasma physics and the formulation of sound design principles have placed the fusion program at the point where theory must meet reality. Proof of scientific feasibility for the application of the fusion reaction will lead to engineering application and concrete results.

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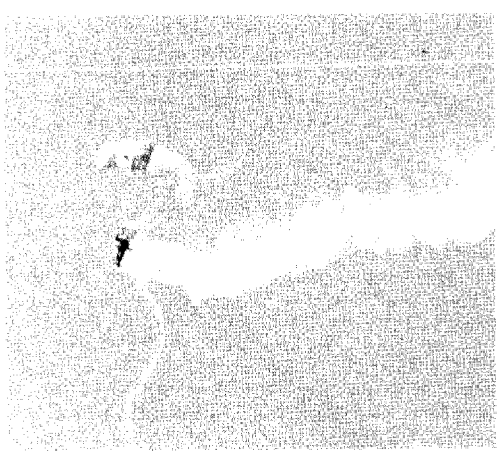

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