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FMIT: A Neutron Factory for Fusion Energy Research

Milton D. Machalek



WHAT IS THE FMIT?

The FMIT (Fusion Materials Irradiation Test) facility will produce large quantities of neutrons—uncharged nuclear particles—to test candidate materials for the world's first fusion reactors. This "neutron factory," a joint effort between HEDL (the Hanford Engineering Development Laboratory at Richland, Washington) and LASL (the Los Alamos Scientific Laboratory at Los Alamos, New Mexico), will be located at HEDL. Its total cost will be \$105 million; of this amount, LASL will spend \$35 to \$40 million to design and develop the particle accelerator necessary to drive the neutron-producing target.

Until now, we have had no appropriate neutron-producing facility where we could evaluate samples of materials for fusion reactor walls. The FMIT will fill this need. It will produce a steady stream of neutrons at the same energy but at even greater intensity than those expected from a fusion reactor. The neutrons will be used to test various materials, such as metal alloys, that will be needed in the reactors. By placing samples in the factory's neutron stream, we will determine the effects of fusion neutrons on the candidate materials and select the best material for the reactor walls.

WHAT IS FUSION ENERGY?

Thermonuclear fusion occurs in the sun, in stars, and to a limited extent in controlled experiments. In the fusion reaction the nuclei of very light atoms, most notably hydrogen, collide with each other and fuse into heavier, more stable nuclei, for example, helium. A large quantity of heat energy is emitted during these reactions.

Scientists around the world have been working for decades to achieve a controlled form of thermonuclear fusion, one that would convert hydrogen, obtained from ordinary water, into large amounts of heat energy to drive steam-electric power plants. In the United States and abroad, hundreds of millions of dollars are being invested in fusion devices such as tokamaks, mirror machines, and fusion lasers.

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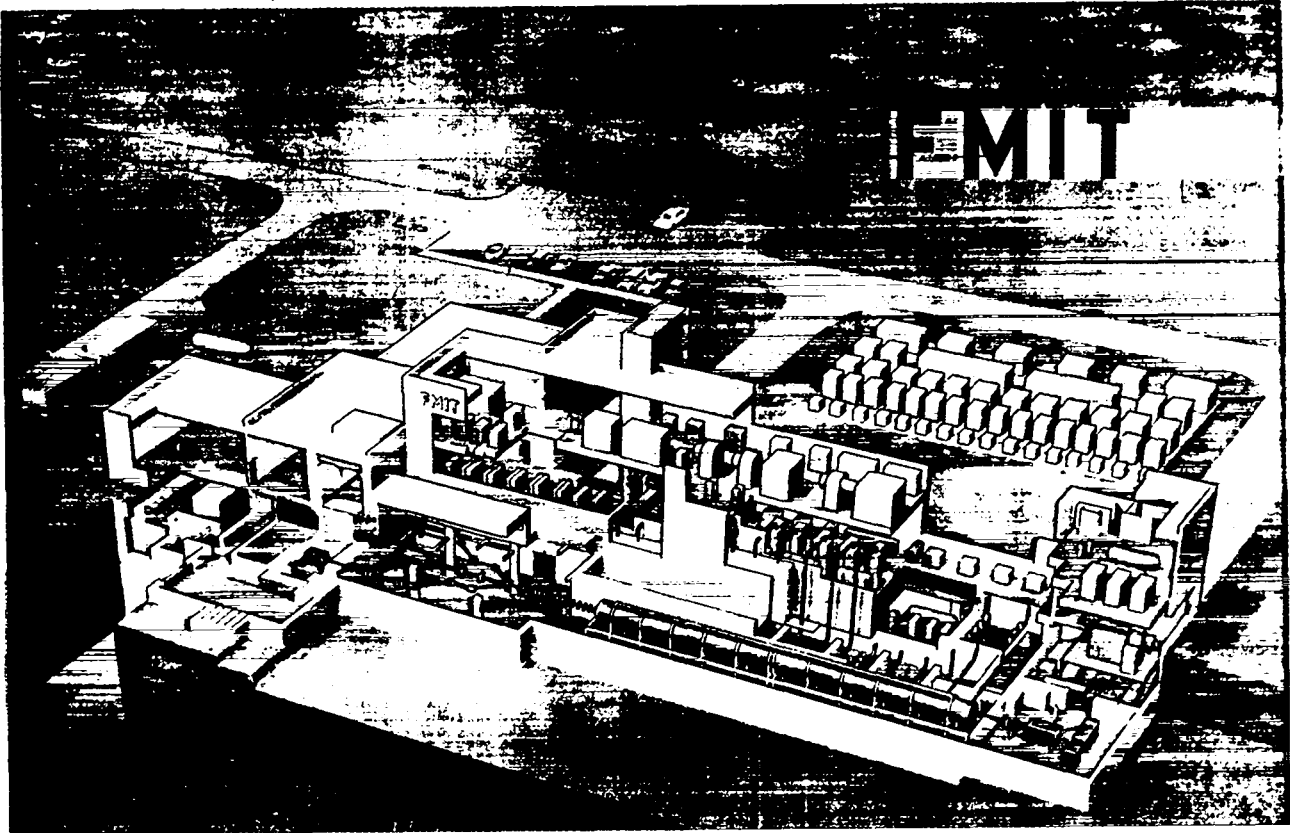
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FMIT. The neutron factory will test materials for use in a fusion reactor. The accelerator is seen in the lower foreground.

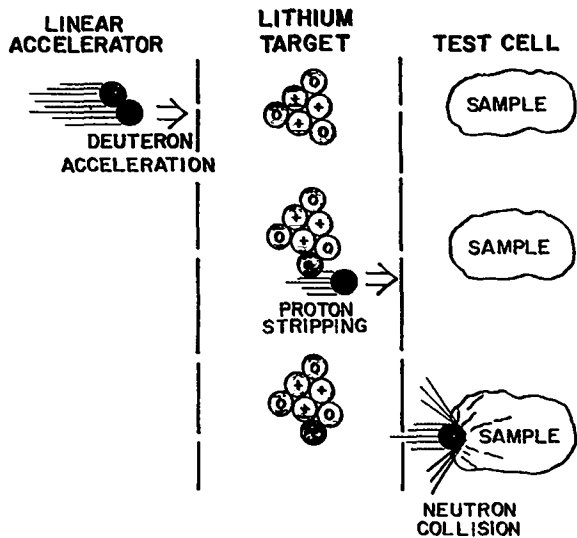
Progress has not been rapid because of the very difficult physics problems associated with fusion, but there is great optimism that by the end of the century we will have energy from the controlled-fusion reaction process.

As we get closer to achieving controlled thermonuclear fusion, we must find a material that can contain the reaction. Actually, no material can withstand the reaction's 100,000,000-degree temperature directly, but to absorb the heat energy, the fusion reactor will need some type of physical container at a suitable distance from the reaction.

While the fusion reaction produces radiant heat energy, it also produces a large number of neutrons. Heat energy can be extracted from the neutrons by absorption into the container walls, but these same neutrons can cause swelling, cracking, and chemical changes in the materials they penetrate, so it is important to choose the wall materials carefully.

HOW ARE NEUTRONS PRODUCED IN THE FACTORY?

In nature, 1 hydrogen atom in 6400 has a neutron attached to its single, positively charged proton nucleus. This proton-neutron nucleus is a form of hydrogen called heavy hydrogen, or "deuterium." To produce a neutron stream, deuterium is injected into the FMIT accelerator and is accelerated to about 35,000 miles per second, or about one-fifth the speed of light. These high-speed deuterium nuclei, called "deuterons," coming out of the accelerator at a rate of a billion-billion per second and each having a 35-million electron volt energy, are directed onto a target of flowing liquid lithium metal. As they pass through the target, the lithium atoms strip off the deuterons' positively charged protons and let the uncharged neutrons pass through the target toward test samples.



Neutron production. High-speed deuterons from the accelerator strike the lithium target, the protons are stripped away, and the neutrons continue on to the sample.

HOW ARE SAMPLES TESTED?

Test samples of candidate materials only a fraction of an inch in size will be placed in the intense neutron stream. Some samples will remain in the stream for only a few minutes; others may be tested for as long as a year. In each case scientists will look for test samples showing the most resistance to neutron-induced damage and thereby will choose the best reactor inner-wall material.

WHAT ARE THE FMIT DESIGN CHALLENGES?

The particle accelerator and the associated lithium target necessary for the FMIT neutron factory both require significant advances beyond present technology. The accelerator will have a 10- to 20-year useful operating life; its output will be 0.1 ampere, which is a billion-billion particles per second. Because most of today's high-current accelerators operate only in a pulsed mode and

produce 10-100 times less current, the FMIT's combined requirements of continuous duty, high current, and high reliability pose a unique challenge to LASL's Accelerator Technology Division. Totally new accelerator techniques are being developed for the FMIT, and a prototype accelerator is being built at LASL to test these techniques.

Similarly, the target requirements of a lithium flow with a smooth liquid surface and an extremely high energy-absorption capability pose unique challenges to HEDL's FMIT Systems Engineering Group. An Experimental Lithium System has been constructed at HEDL to test target configurations.

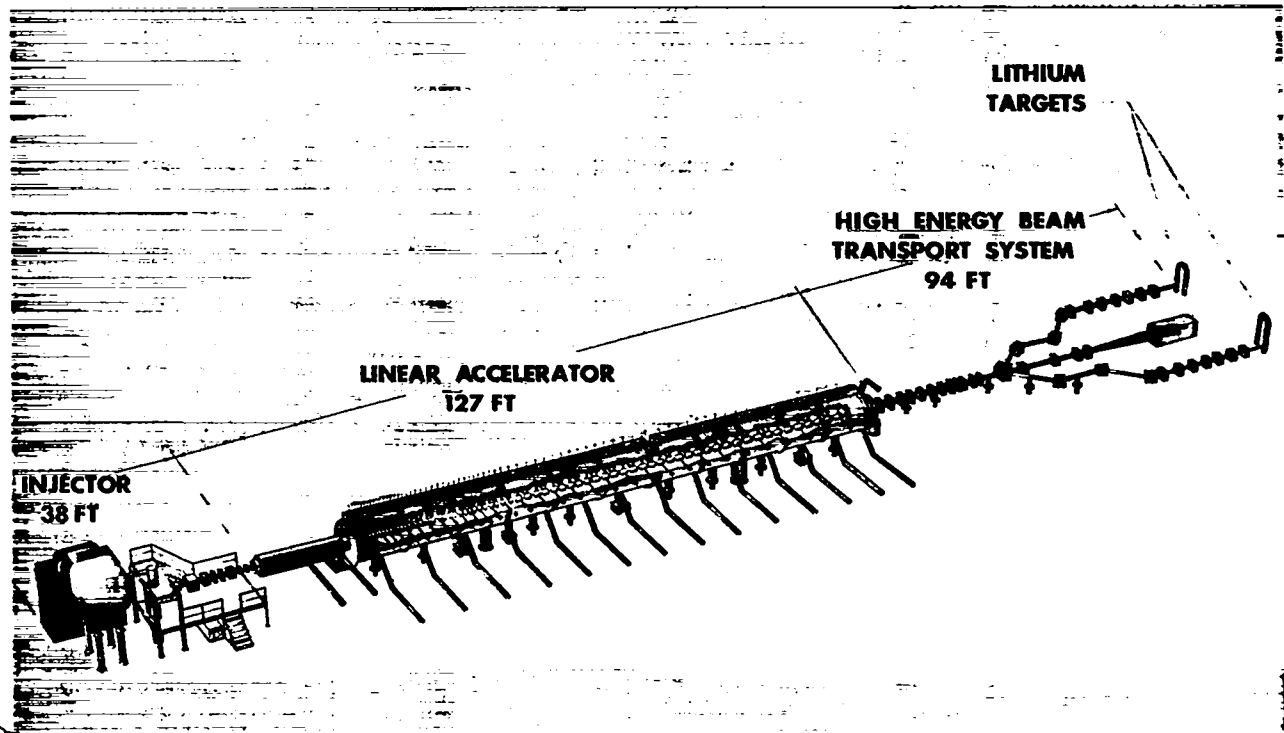
WHAT ARE THE FMIT'S BENEFITS?

Scientists researching fusion energy believe that it will be the ultimate energy source for our planet. Hydrogen fuel, obtained from water, is abundant, and the amount of radioactivity produced by fusion is less than the amount produced by fission reactor plants. Scientists continue to work diligently to

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FMIT accelerator. Atomic nuclei of deuterium introduced by the injector into the linear accelerator are accelerated to one-fifth the speed of light. These high-speed particles are conducted by a high-energy beam transport system to either of two lithium targets, where neutrons for testing materials are produced.

achieve controlled thermonuclear fusion—which is perhaps the most difficult scientific and engineering problem ever faced by man. We think that we are very close to achieving control of fusion; however, beyond this stage much work will be needed to build a power-producing reactor.

The FMIT will make significant contributions to the first fusion reactor design by providing information for the selection of reactor materials. These contributions will hasten the time when the world will benefit from abundant electrical power produced by fusion.

ABOUT THE AUTHOR

Milton D. Machalek is Associate Group Leader of the High-Intensity Deuteron Linac Group of LASL's Accelerator Technology Division. He is a plasma physicist who holds degrees in physics from the University of Texas, the University of Chicago, and Harvard University. In 1974 Dr. Machalek joined LASL's Controlled Thermonuclear Research Division where he worked in magnetically confined fusion energy research. In 1978 he transferred to AT-Division's FMIT project.

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 to correspond directly
 with the author.