INTERNATIONAL ATOMIC ENERGY AGENCY

FIFTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Seville, Spain, 26 September – 1 October 1994

CONF-940933--35

IAEA-CN-60/F-2-II-5

THE INTERNATIONAL FUSION MATERIALS IRRADIATION FACILITY

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[1]Research sponsored by the Office of Fusion Energy, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

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ABSTRACT

It is widely agreed that the development of materials for fusion systems requires a high flux, 14 MeV neutron source. The European Union, Japan, Russia and the United States have initiated the conceptual design of such a facility. This activity, under the International Energy Agency (IEA) Fusion Materials Agreement, will develop the design for an accelerator-based D-Li system. The first organizational meeting was held in June 1994. This paper describes the system to be studied and the approach to be followed to complete the conceptual design by early 1997.

1. THE NEED FOR A FUSION NEUTRON SOURCE

In fusion energy systems, materials activation and radiation damage from the high energy neutrons define the primary issues related to environmental, safety, and health concerns. Fusion blanket and first-wall components constructed from traditional structural materials, such as stainless steel, would have useful lifetimes of only a few years and their neutron activation would create hazardous wastes lasting for thousands of years. Several materials have been identified that could significantly lower the activation. These include vanadium, new steel compositions, and silicon carbide composites. However, the characterization, development, and qualification of materials for fusion will require testing in an environment that includes the 14-MeV neutrons characteristic of D-T fusion.

There is a worldwide consensus that a high-flux, 14-MeV neutron source is necessary to support the development of materials for a demonstration fusion power plant. If such a facility is operational within the next ten years, it can also contribute to the validation of materials performance choices for the International Thermonuclear Experimental Reactor.

2. ORGANIZATION OF AN INTERNATIONAL CONCEPTUAL DESIGN

There is considerable confidence that a 14-MeV neutron source could be constructed based on presently existing technology. The United States was well along in development and construction of the Fusion Material Irradiation Test (FMIT) facility [1,2] in the early 1980's when the project was canceled due to budget cuts in the national fusion program. The ultimate need for such a facility was recognized internationally and work continued in spite of the demise of FMIT. The most complete and thorough study in the last decade has been conducted by the Japan Atomic Energy Research Institute at Tokai, Japan. Starting in 1988, they developed the concept of the Energy Selective Neutron Irradiation Test (ESNIT) [3], a project similar to, but somewhat smaller in scope than, the FMIT. This project then led to a series of workshops sponsored by the IEA to explore options and assess international interest in a fusion neutron source [4].

A workshop arranged by the IEA was held in Moscow in July 1993, to specifically explore the technical and organizational options for proceeding on an international design study for a fusion neutron source project. The workshop, which included technical experts from the European Union, Japan, Russia, and the United States, agreed on a technical approach consisting of an accelerator-based D-Li beam target system based on the FMIT concept. It was agreed that system characteristics adequate to allow lifetime testing of materials for a demonstration power plant must be achieved. A conceptual design activity was recommended as the next step in preparing for a possible future project. In February 1994, the Fusion Power Coordinating Committee of the IEA directed the Fusion Materials Executive Committee to proceed with the conceptual design.

On June 13–15, 1994, representatives of Japan, the European Union, and the United States met in Tokai, Japan, to recommend a plan for the conceptual design of a high-flux fusion neutron source. This meeting was successful in defining the technical requirements for the design and a procedure and time schedule to produce a conceptual design by January 1997.

The representatives at Tokai discussed an approximate organization for the conceptual design activity as depicted in Fig. 1. The activity will be carried out under the executive committee for the IEA Fusion Materials Agreement. A steering committee of one representative per participating party will review the progress, and prepare and advise their parties on administrative matters and funding needed by each party to continue the work. A group of materials science "Users" of the conceived neutron source will make significant comment on the work in progress on the design, in particular for the test assembly portion of the design. The function of design integration will be carried out by a group consisting of one technical leader from each participating party.

It was recommended that the conceptual design activity should start by identifying and dividing work among participants and conducting technical work at home sites. A technical workshop in Karlsruhe, Germany, on September 26–30, 1994, was charged with the following:

- define a baseline concept and critical issues;
- identify working groups and shared procedures such as a computer system for communications and document sharing;
- list and distribute all available information accumulated on the D-Li neutron source approach as soon as possible; and
- define the next work to be accomplished following an approximate format and time schedule.

3. TECHNICAL FEATURES

The basic design features and operating parameters of the neutron source were discussed at the Moscow and Tokai workshops. The D-Li concept, with neutron production by the stripping reaction of energetic deuteron particles impacting a liquid lithium target, was accepted as the best compromise of neutron source characteristics and available, developed technology. The concept for forming the neutron "beam" is illustrated in Fig. 2. In addition to simple splitting of the deuterons into protons that stop in the lithium target and neutrons that pass through, some nuclear reactions will occur in the target. These reactions result in a few neutrons at energies up to nearly 50 MeV.

The high flux test volume of approximately one liter is required to provide an array of specimens necessary to develop and test materials in conditions similar to those expected at the first wall and blanket of a fusion power reactor. Typical parameters, selected to meet the materials development mission, are as follows:

Deuterium Beam Current	250 mA
Beam Energy	30-35 MeV
Beam Spot Size	10 cm × 10 cm
Target	Lithium Jet With Back Plate
Test Volume	Approximately 1 liter (flux equivalent of 2 MW/m^2)

The facility design would consist of a minimum of two beamlines, each with a current of 125 mA. The design of the lithium system has been established by the work on FMIT; however, better understanding of the thermal-hydraulic response at the beam interaction area requires more detailed design and analysis. In order to obtain neutron fluences useful for materials development for a demonstration fusion power plant, the beam current must exceed those of FMIT or ESNIT, and a plant availability of 70% or greater is required. The availability goal represents the greatest challenge to the design and development of the facility. Special configuration and maintenance layouts will be required for reliable long-term operation.

It is not yet established whether and when a modified legal framework and physics R&D are required to accommodate a credible reference design. R&D volunteered by any of the parties could, of course, help to clarify the needs. The steering committee will review the outcome of the Karlsruhe technical workshop and make further recommendations.

The design integration group should anticipate preparing an interim report that provides a design requirements document and a plan for completing the reference conceptual design by October 1995. A more intense effort, beginning as soon as October 1995, will complete a final reference design report that could be used by the parties, or any one of the parties, in decisions on how to realize the needed neutron source.

4. TECHNICAL GOALS OF THE CONCEPTUAL DESIGN

The initial activities of the conceptual design will involve the four parties under the Executive Committee of the IEA Fusion Materials Agreement, with the responsibility for coordinating the activity assigned to Japan. The initial tasks will include evaluation of the design options for the main components of the accelerator and target systems. These will include the choices of accelerator types, the trades between normal and superconducting accelerator technologies, accelerator architecture and overall system configuration. A detailed analysis of the use of the facility, including the development of requirements for the test cell loading and specification of the experimental program will be generated to guide the facility design.

A possible schedule of milestones was discussed at Tokai; these are first suggestions that will be reviewed and revised by the working group.

• Form International Procedural Concept	June 1994
• Initial Requirements and Design Layout	October 1994
• Initial Report to FPCC	February 1995
• Establish Baseline Design	March 1995
• Preliminary System Design Layouts	July 1995
• Interim Report, Design Requirements, and Plan	October 1995
• Define R&D Needs	December 1995
• Estimate Cost/Schedule for Construction	April 1996
• Environment, Safety and Site Requirements	September 1996
• Conceptual Design Complete	January 1997

Since this neutron source facility is required for the qualification of materials, such a facility is needed as soon as possible to allow the orderly development of fusion energy. Therefore, the conceptual design of this neutron source concept must be completed as quickly as possible.

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[3] NODA , K., et al., "Capability of Energy Selective Neutron Irradiation Test Facility (ESNIT) for Fusion Reactor Materials Testing and the Status of ESNIT Program," pp. 13–17 in *International Advisory Meeting on ESNIT, JAERI, February 1-2, 1993.*

[4] International Fusion Materials Irradiation Facility (IFMIF) Workshop, San Diego, Ca., February 1989, Vol 1: Evaluation Report and Vol. 2: Technical Presentations.

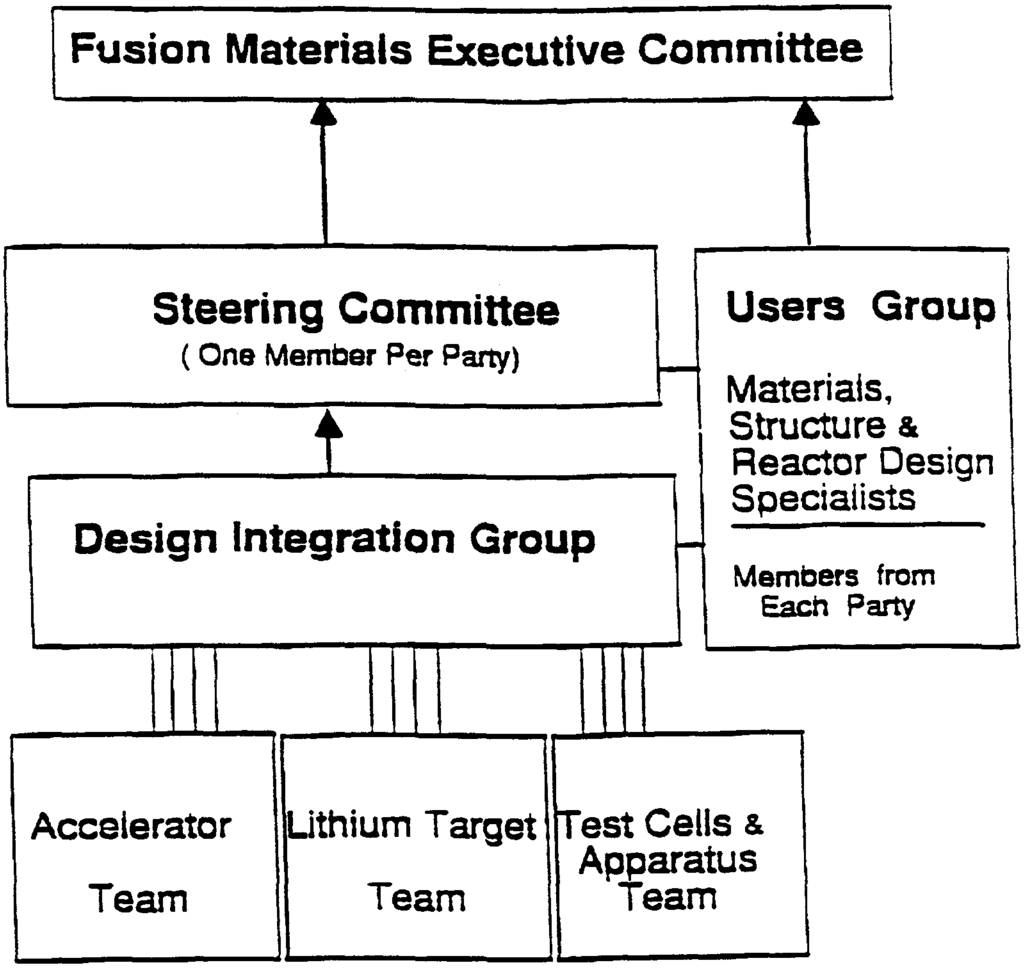

Fig. 1. Organization Structure for International Fusion Material Irradiation Facility Conceptual Design Activity

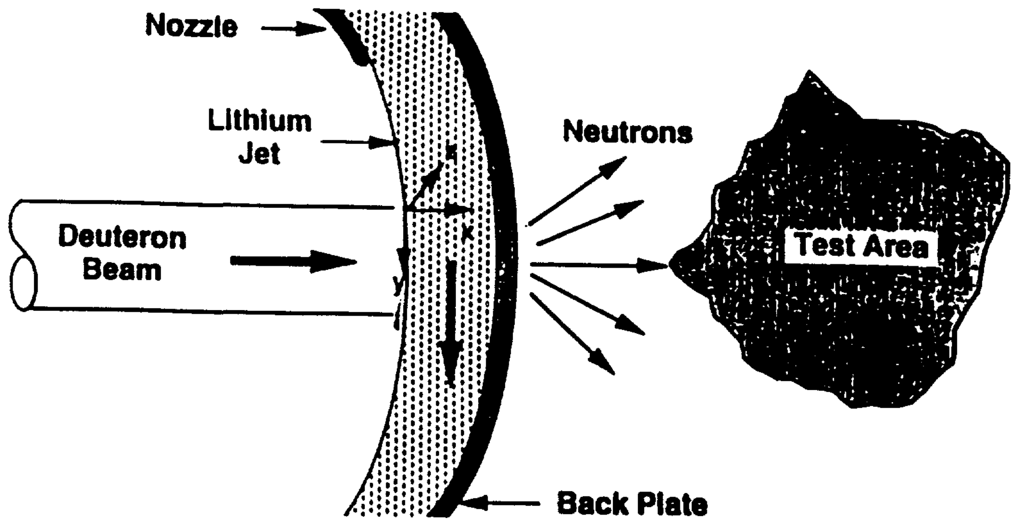

Fig. 2. Schematic of method for producing a "14 MeV neutron beam". A beam of 35 MeV deuterons is split into protons and neutrons by collisions in the lithium jet target. The protons are stopped in the lithium jet. The neutrons are slightly degraded in velocity and thus emerge from the jet at a little less than one half the original deuteron energy.