CONCEPTUAL DEVELOPMENT OF FUSION-2 EXPERIMENT FOR IRRADIATION TESTING OF VANADIUM ALLOYS IN A LITHIUM ENVIRONMENT AT ≈500-750°C IN THE BOR-60 REACTOR[1] – V. Kazakov, V. Chakin, V. Efimov, V. Petukhov, A. Tuktabiev, P. Gabiev (Research Institute of Atomic Reactors), H. Tsai, T. S. Bray, D. L. Smith (Argonne National Laboratory); and A. Rowcliffe (Oak Ridge National Laboratory)

OBJECTIVE

BOR-60 is a sodium-cooled fast reactor in Russia with a coolant inlet temperature of 300-330°C. Previous irradiation experiments conducted in the BOR-60, EBR-II, HFIR, ATR, and SM reactors indicate that the threshold for low-temperature embrittlement of vanadium-base alloys is ≈400°C. The purpose of the proposed Fusion-2 experiment in BOR-60 is to study the effects of neutron damage in vanadium-base alloys at or just near the high-temperature end, i.e., 500-750°C. The objective of the present task is to develop the conceptual design of the experimental assembly based on the functional requirements of the experiment. Conceptual development focuses on construction of the experimental assembly, methods of temperature control and measurement, thermal performance of the assembly, and feasibility of conducting assembly and disassembly in the Research Institute of Atomic Reactors (RIAR), where BOR-60 is located.

SUMMARY

The requirements of this task are to complete the conceptual designs of irradiation capsules to be exposed to a neutron dose of ≈20 dpa in BOR-60. The specimen matrix will include sheet tensile specimens, compact tension specimens, bend bars, TEM disks, and pressurized creep tubes. To better utilize the test volume and provide additional temperature options, it was decided to modify the experiment from a two-capsule to a three-capsule design. All capsules will be liquid-metal-bonded for temperature uniformity. Goal temperatures for the three capsules will be 450, 600, and 700-750°C, with an emphasis on 600°C. A key objective of the experiment will be to generate irradiation creep data for vanadium-base alloys, especially at the emphasized temperature of 600°C, where thermal creep may not be dominant.

PROGRESS

The design for Fusion-2 would be similar to that shown in Fig. 1, with the exception of the number of axially-arranged capsules, which would be increased from two to three. A three-capsule design would permit better utilization of the high-value, high-flux space at the core midplane and, because each capsule can operate at a different temperature, a more diverse study of temperature effects on irradiation. By adopting three shorter capsules, there would also be less axial power/temperature tilt in each capsule would be reduced.

The materials of construction for the Fusion-2 experiment would be as shown in Table 1. The double-wall capsule (Item 3) would be made of austenitic stainless steel or Inconel for compatibility with the bond sodium at elevated temperature. The subcapsules (Items 4 and 5) containing the test specimens would be made of TZM (an Mo-base alloy) for impurity control and compatibility with the specimen lithium bond. There would be two sizes of subcapsules; those of smaller diameter (Item 5) are sized to accommodate pressurized creep tubes.

Preliminary thermal analysis has been conducted, and the results indicate that a wide range of irradiation temperatures are attainable in the Fusion-2 experiment with this design. For performance assessment of the vanadium-base alloy for fusion applications, we decided that the most important test temperature at this time would be 600°C. Accordingly, the high-flux middle capsule would be allocated for this temperature. Because the lengths of the three capsules need

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not be the same, the middle capsule would be slightly elongated to provide a ≥40% total test volume. The top and bottom capsules would be designed for 700-750 and 450°C, respectively, and would have a smaller test volume than that of the middle capsule.

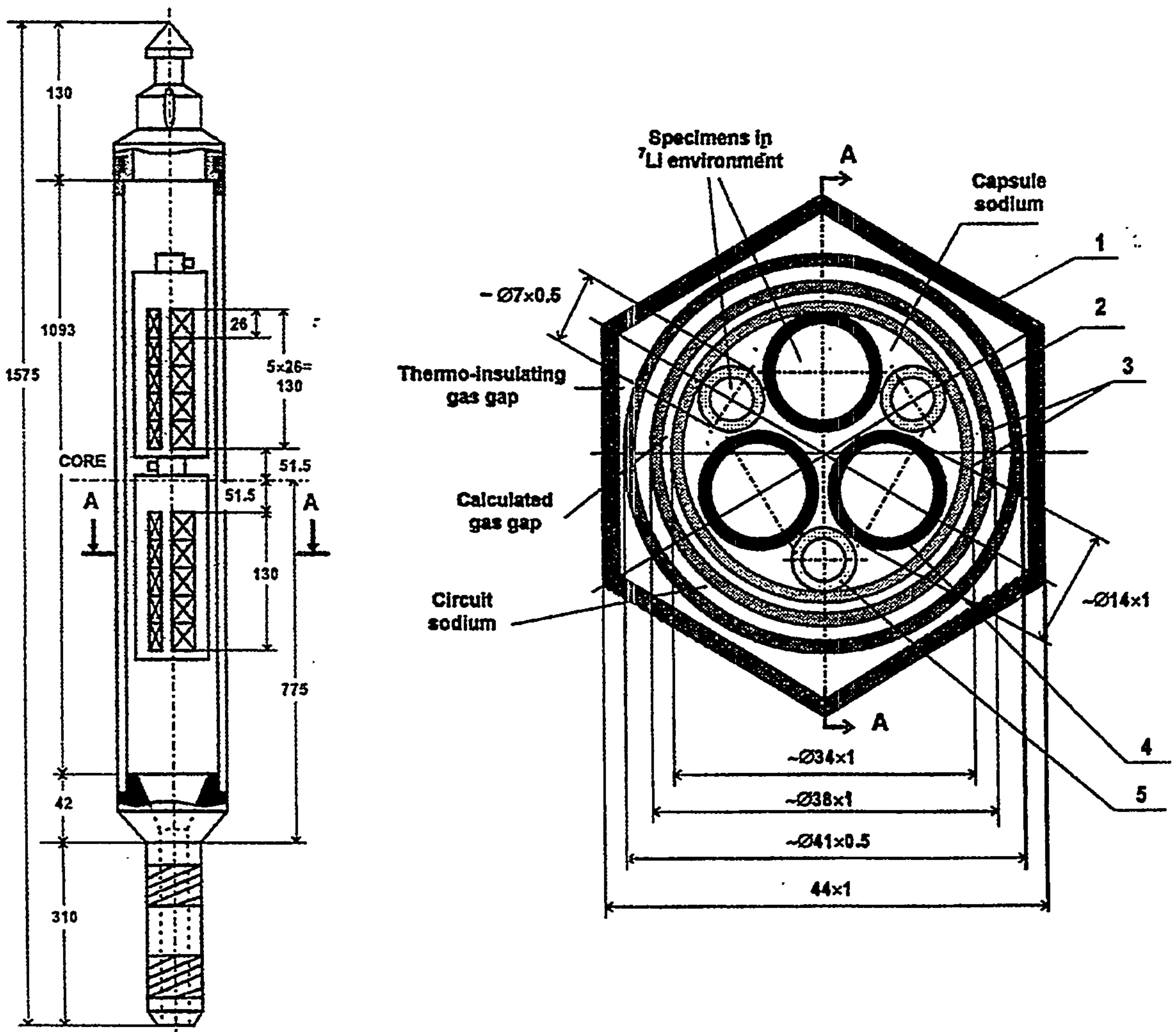

Fig. 1. Fusion-2 test vehicle (left, showing two capsules) and cross section of capsule (right). Note: design is being revised to accommodate three axial capsules.

Table 1. Materials of construction for Fusion-2 test assembly

Item No.	Test Temperature = 450, 550, 600°C	Test Temperature = 700°C	Fill Medium
1	Hex Can	Hex Can	He
2	SS	SS	Na
3	304 SS	Inconel	He (outer) Na(inner)
4	Mo alloy of TZM or VM-1A type	Mo alloy of TZM or VM-1A type	Li-7, specimens
5	Mo alloy of TZM or VM-1A type	Mo alloy of TZM or VM-1A type	Li-7, specimens

Another decision made in this reporting period was to forego the option of conducting a dynamic helium charging experiment (DHCE) in Fusion-2. (In a DHCE, tritium is implanted in the capsule. During irradiation, some of the tritium diffuses into the specimen and decays in-situ into ^{3}He, thereby yielding the concurrent effects of helium generation and neutron damage.) This decision was made to ease the logistic constraint of tritium handling/transport and to provide additional time to better prepare for such an eventual experiment.

To monitor the specimen temperature, a limited number of thermocouples would be incorporated in the top and middle capsules in the Fusion-2 vehicle. Because only one core location (D-23) in BOR-60 permits deployment of thermocouples, the Fusion-2 experiment would be irradiated at this location, at least at the onset of the experiment. If this location is available for the entire irradiation time and the cost is not prohibitive, the Fusion-2 capsule would remain at D-23 for the entire ≈1-year irradiation to ≈20 dpa. Otherwise, it would be irradiated for a finite period, possibly several weeks, at D-23 to confirm the test temperatures before being relocated to a comparable core location (possibly E-23) to complete the irradiation.

Steady irradiation temperature is important in testing structural materials samples. For pressurized creep specimens, this is particularly, because temperature fluctuation affects not only creep properties but also internal gas pressure. Means to ensure steady irradiation temperatures are being explored.

Future Activities

The Fusion-2 conceptual design effort will be completed in the next reporting period. A full assessment of the experiment based on the optimized design will be conducted.

REFERENCE

1. V. Kazakov et al., "Conceptual Development of Fusion-2 Experiment for Radiation Test of Vanadium Alloys in BOR-60 Reactor at 500-700°C in Lithium Environment," Report on Milestone 1 of Subcontract 28X-SZ738V of 06/08/98 with Lockheed Martin Energy Systems, Inc., USA, 1998.