NEW IRRADIATION FACILITIES IN THE OAK RIDGE HIGH FLUX ISOTOPE REACTOR (HFIR)

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ABSTRACT

Modifications have been made to the High Flux Isotope Reactor (HFIR) which permit the operation of instrumented irradiation capsules in the target region, and more and larger capsules in the removable beryllium region. As many as two instrumented target capsules can now be accommodated and positions for up to eight 46-mm-diam instrumented capsules are now available in the removable beryllium region. One instrumented target capsule has already been irradiated and new capsules have been prepared for irradiation in the removable beryllium region.

1. INTRODUCTION

The High Flux Isotope Reactor (HFIR) is a pressurized, light-water-cooled, beryllium-reflected, 85-MW reactor. The HFIR was designed for the production of isotopes, particularly transuranium isotopes. This production requires high thermal and epithermal fluxes; indeed, the HFIR target region (the cylindrical space inside the two concentric annular fuel elements) has the highest steady-state thermal neutron flux in the world. The relatively high reactor power and power density leads to a high fast neutron flux near the core, so that the HFIR is also used for materials irradiation experiments.

While the HFIR had outstanding neutronics characteristics for materials irradiations, some relatively minor aspects of its original mechanical design severely limited its usefulness for that purpose. In 1984, an ad hoc committee was established at the Oak Ridge National Laboratory (ORNL) to "... consider and recommend changes and improvements to the Laboratory's facilities for materials irradiation testing." The committee's report [1] included recommendations for certain modifications to the HFIR that would significantly enhance the number and value of materials irradiation experiments that could be accommodated by the reactor.

The basic improvements that were needed to provide better materials irradiation facilities at the HFIR were in two areas. The highest flux positions in the target region could not be instrumented, and the removable beryllium (RB) positions were few and much smaller than those of general purpose reactors. These deficiencies have been remedied through the HFIR Irradiation Facilities Improvement (HIFI) Project which has provided two instrumented target region facilities and larger and additional RB irradiation positions with straight-line access penetrations through the pressure vessel.

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2. DESCRIPTION OF FACILITIES

A general arrangement of the new materials irradiation facilities with typical instrumented target and RB capsules in place is shown in Fig. 1. The characteristics of these facilities are presented in Table 1.

Providing instrumented target facilities required newly designed and fabricated components from the bottom to the top of the reactor "stack." These components included a fuel grid, target holder, target tower, target hole plug, quick-access hatch, rabbit facility U-bend, and several in-pool tools for removing and replacing components. The target tower extends upward from the target region to a quick-access hatch and target hole plug in the pressure vessel lid. The tower houses three guide tubes - one for the hydraulic rabbit facility and the other two for the instrumented target facilities.

With these components modified, at least two small target capsules of 16-mm-diam may be instrumented. The guide tubes in the target tower are large enough such that by occupying up to seven target positions, capsules of up to 25-mm-diam can be accommodated (Fig. 2).

The new RB facilities required a modified design for the reflector, replacing the four 37-mm-diam positions with eight holes, each with a 48-mm diam. This change increased the total experimental volume available within the removable beryllium by a factor of greater than 3. These new positions are referred to as the RB Star (RB*) facilities.

In addition, several components above the beryllium and the core were modified to provide straight-line access to all eight of the RB* positions. The straight-line access permits rotation and vertical relocation of irradiation capsules during the course of an experiment and facilitates experiment interchangeability.

Recording and control equipment is in place to operate two singly-contained capsules and two doubly-contained capsules, with space readily available to expand the equipment for the operation of a total of eight fully instrumented capsules.

3. TYPICAL EXPERIMENTS

Significant funding for the necessary modifications was provided by the Magnetic Fusion Energy (MFE) program. The first instrumented target capsule was the target temperature test (TTT) capsule. It was a part of the US/Japan fusion materials program and was irradiated to determine more accurately the probable temperature in the uninstrumented target capsules previously irradiated as part of that program. Two thermocouple array tubes (TCATs), each having seven thermocouple junctions, were used to measure the centerline temperature of mock specimens. The experiment performed well, and revealed (Fig. 3) that the gamma heating decreases much more rapidly at the ends of the capsule then had previously been thought. A general configuration of the TTT capsule is shown in Fig. 4.

The larger reflector positions permit spectral tailored experiments, similar to those previously performed in the Oak Ridge Research Reactor (ORR), to be performed in the HFIR where fluence can be achieved in about half the time. Indeed, MFE specimens irradiated in ORR spectral tailored capsules have been retrieved and are being reencapsulated for continued irradiation in HFIR RB* positions. Toward this end, series of experiments have been designed to

Fig. 1. The High Flux Isotope Reactor (HFIR).

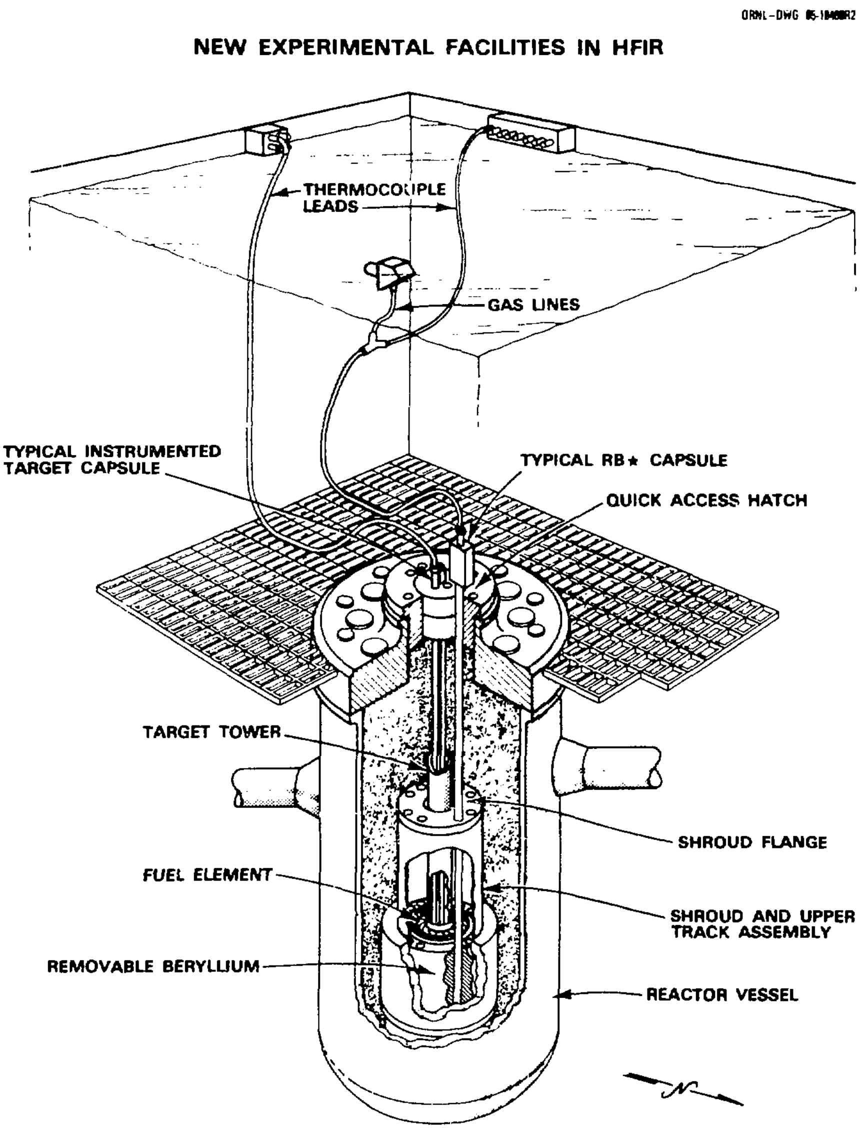


Table 1. Characteristics of primary HFIR materials irradiation facilities

Characteristics	Irradiation position	
	RB	Target
Fast neutron flux, E > 0.1 MeV (10^{18} $m^{-2}s^{-1}$)	6	12
Thermal neutron flux (10^{18} $m^{-2}s^{-1}$)	13	24
Maximum displacements per atom per calendar year, stainless steel	8	25
Gamma heating (W/g SS)	14	47
Typical capsule diameter (mm)	46	16[a]
Typical capsule length (mm)	500	500
Number of available positions	8[b]	>20[c]
Minimum specimen temperature (°C)	60	60
Instrumentation	Yes	Yes[d]
Typical fuel cycle length (days)	25	25

[a]By occupying up to seven positions, 25-mm-diam can be accommodated.

[b]Plus four smaller positions, ~12-mm diam.

[c]A total of 37 target positions exist. The number available depends on the number being used for transuranium isotope production.

[d]Two target positions can accommodate instrumented capsules.

Fig. 2. Instrumented target positions illustrating capability of accommodating 25-mm capsules.

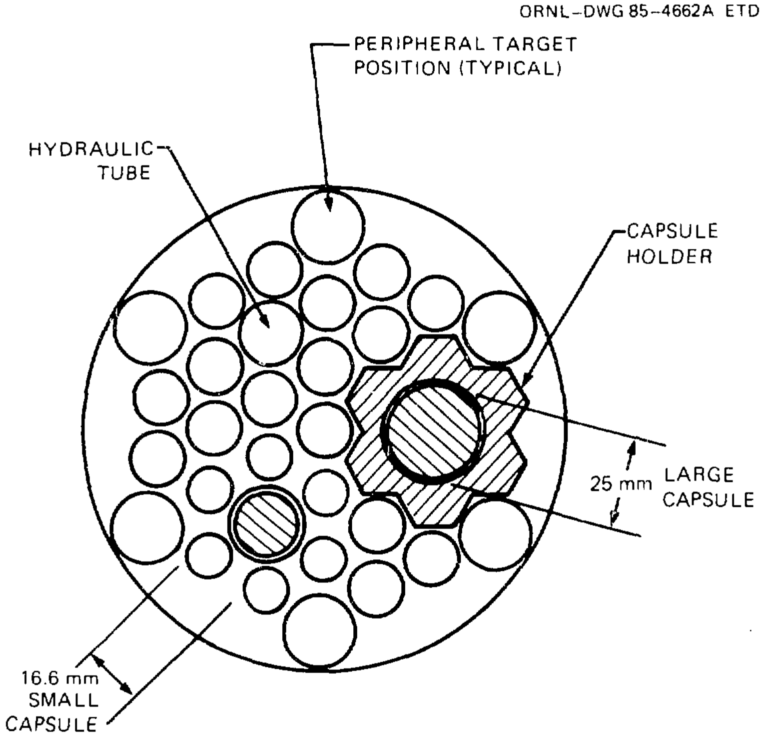


Fig. 3. Heat generation in HFIR target region (data is for 100 MW and should be multiplied by 0.85 to obtain present values).

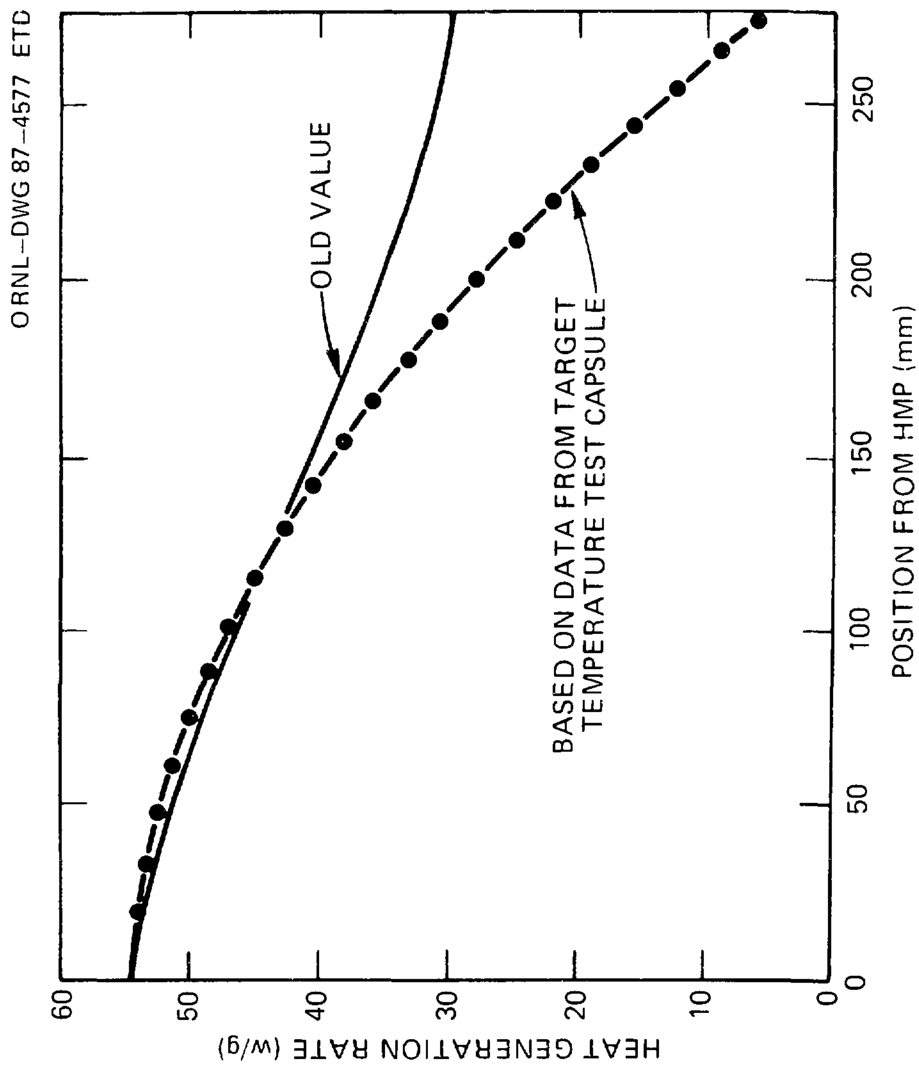
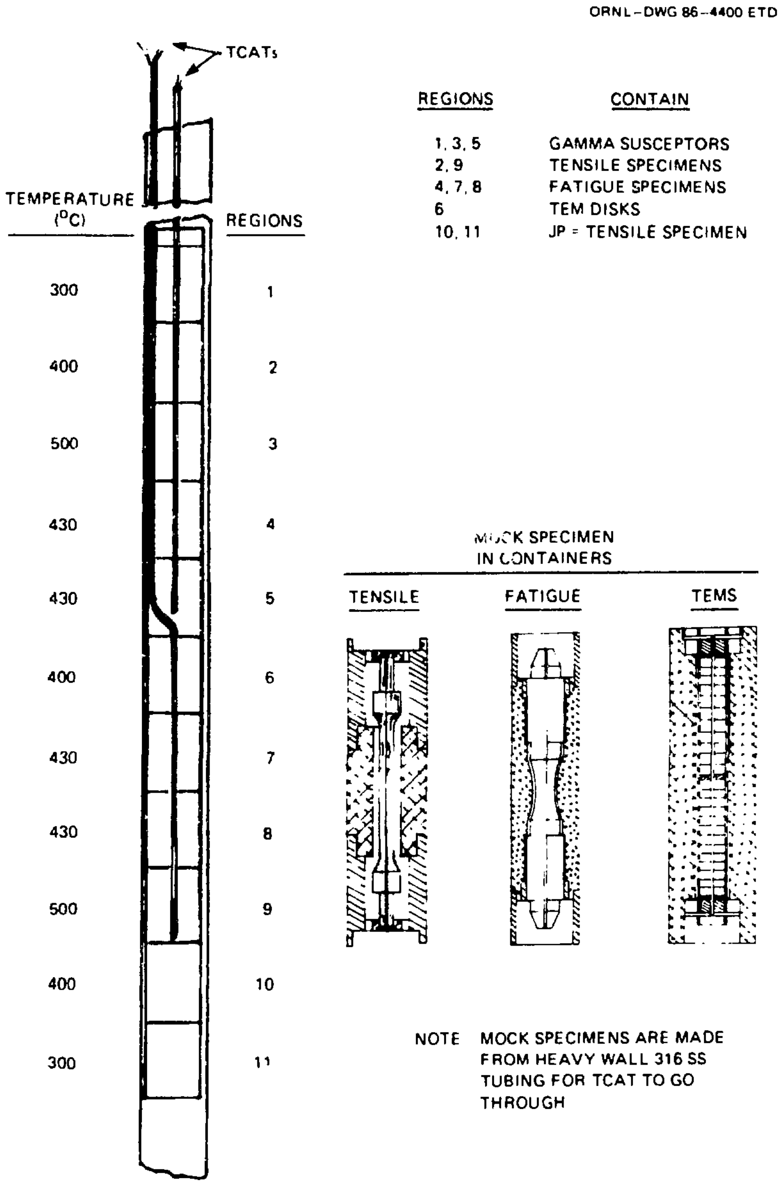


Fig. 4. General configuration of TTT capsule.



irradiate up to 250 mechanical property specimens each at temperatures of 60, 200, 330, and 400°C [2]. Around each of these experiments will be a 4.2-mm thick Hafnium sleeve which will reduce the thermal neutron flux by about 85%, thus permitting the specimens to receive the same helium production-to-displacements per atom (He/dpa) ratio as is expected in the first wall of a MFE device. Horizontal and vertical cross sections through the 330°C capsule are shown in Fig. 5.

New RB* capsules have also been assembled for the High Temperature Gas-Cooled Reactor (HTGR) program. These will irradiate coated particle fuel compacts in a graphite fuel body. A horizontal cross section through a typical HTGR fuel capsule is shown in Fig. 6.

4. SUMMARY

These new HFIR facilities provide the materials irradiation community with very powerful tools with which to carry on its work. The HFIR should now be considered a world-class materials testing reactor; in the case of the instrumented target capsules, it surpasses any reactor for the magnitude of neutron flux available in instrumented irradiation experiments.

5. REFERENCES

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2. A. W. Longest, J. E. Corum, D. W. Heatherly, and K. R. Thoms, "Design of spectrally-tailored fusion reactor materials experiments in the HFIR RB* capsule irradiation facility," J. Nucl. Mater. 155-157 (1988) 1340-1345.

Fig. 5. Lower half of the HFIR-MFE-330J-1 capsule.

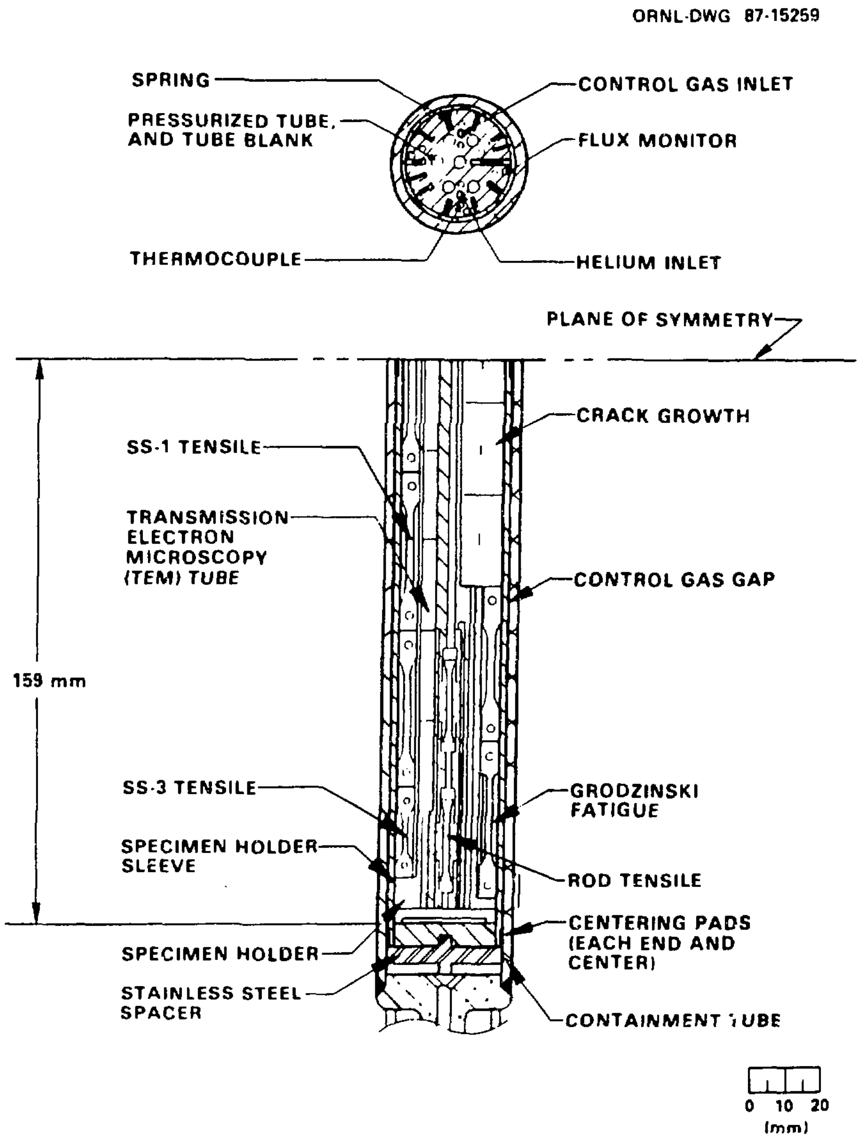

Fig. 6. Horizontal section through irradiation capsule HRB-21.