IRRADIATION RESEARCH CAPABILITIES AT HFIR AND ANS*

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EXTENDED ABSTRACT

A variety of materials irradiation facilities exist in the High Flux Isotope Reactor (HFIR) and are planned for the Advanced Neutron Source (ANS) reactor. The HFIR, while designed primarily for transuranium isotope production, has since 1970 been utilized for various materials irradiation programs. Approximately 80 uninstrumented capsules have been irradiated in the target region for the Magnetic Fusion Energy (MFE) and High Temperature Gas-cooled Reactor (HTGR) programs. Additionally, 20 instrumented capsules have been irradiated in the removable beryllium (RB) region for the HTGR program.

In 1986 the HFIR Irradiation Facilities Improvement (HIFI) project began modifications to the HFIR which now permit the operation of two instrumented capsules in the target region and eight capsules of 46-mm OD in the RB region. Thus, it is now possible to perform instrumented irradiation experiments in the highest continuous flux of thermal neutrons available in the western world. The new RB facilities are now large enough to permit neutron spectral tailoring of experiments and the modified method of access to these facilities permit rotation of experiments thereby reducing fluence gradients in specimens. A summary of characteristics of irradiation facilities in HFIR is presented in Table 1.

The ANS is being designed to provide the highest thermal neutron flux for beam facilities in the world. Additional design goals include providing materials irradiation and transplutonium isotope production facilities as good, or better than, HFIR. The reference conceptual core design consists of two annular fuel elements positioned one above the other instead of concentrically as in the HFIR. Each element will be 507-mm long providing an overall core height of slightly more than 1 meter.

A variety of materials irradiation facilities with unprecedented fluxes are being incorporated into the design of the ANS. These will include fast neutron irradiation facilities in the central hole of the upper fuel element, epithermal facilities surrounding the lower fuel element, and thermal facilities in the reflector tank. A summary of characteristics of irradiation facilities presently planned for the ANS is presented in Table 2.
Table 1. Characteristics of some irradiation facilities in HFIR

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Target</th>
<th>RB*</th>
<th>Small VXF</th>
<th>Large VXF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast flux, E &gt; 0.1 MeV (10^{18} neutrons m^{-2} s^{-1})</td>
<td>12</td>
<td>6</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Maximum displacements per calendar year, stainless steel</td>
<td>25</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal flux (10^{18} neutrons m^{-2} s^{-1})</td>
<td>24</td>
<td>14</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Gamma heating (W/g SS)</td>
<td>46</td>
<td>16</td>
<td>3.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Typical capsule diameter (mm)</td>
<td>16</td>
<td>46</td>
<td>37</td>
<td>69</td>
</tr>
<tr>
<td>Number of available positions</td>
<td>36</td>
<td>8</td>
<td>16</td>
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Table 2. Characteristics of materials irradiation facilities in ANS

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Inside CPBT</th>
<th>In reflector tank</th>
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<tr>
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<td>Central positions</td>
<td>Transuranium production positions</td>
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<td>63</td>
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MAJOR MATERIALS IRRADIATION FACILITIES

HFIR

- Target region
- RB* facilities
- Permanent beryllium

ANS

- Central (fast)
- Reflector (thermal)
THE OAK RIDGE HIGH-FLUX ISOTOPE REACTOR (HFIR)

- A pressurized, light-water-cooled, beryllium-reflected, 85-MW research reactor

- Specifically designed and built for the production of transuranium isotopes
  - The highest continuous flux of thermal neutrons in the western world

- Also used for neutron-beam scattering experiments

- Also used for engineering materials irradiations
  - Fusion materials
  - HTGR fuel and graphite
  - Pressure vessel steel samples

- Low coolant water temperature - Inlet 49°C and Outlet 73°C

- Typical fuel cycle length of 25 days
A VARIETY OF IRRADIATION FACILITIES ARE AVAILABLE IN HFIR

- Target Region
  - Uninstrumented
  - Instrumented
  - Hydraulic tube

- RB*

- Vertical Experimental Facilities in Reflector
  - Small
  - Large
  - Pneumatic tube
PLAN VIEW OF THE HFIR SHOWING REACTOR COMPONENTS, FUEL, AND BEAM TUBES

- Reactor pressure vessel
- Thru tube
- Removable reflector
- Inner fuel element
- Semipermanent reflector
- Control plates
- Target region permanent reflector
- Tangential tube
- Outer fuel element irradiation positions
- Radial tube
- Ornl
NEW EXPERIMENTAL FACILITIES IN HFIR

TYPICAL INSTRUMENTED TARGET CAPSULE
TYPICAL RB* CAPSULE
QUICK ACCESS HATCH
TARGET TOWER
FUEL ELEMENT
REMOVABLE BERYLLIUM
SHROUD FLANGE
SHROUD AND UPPER TRACK ASSEMBLY
REACTOR VESSEL
Characteristics of some irradiation facilities in HFIR

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SS-3 TENSILE PRESSURIZED TUBE AND TRANSMISSION ELECTRON MICROSCOPY (TEM) REACTOR HORIZONTAL MID-PLANE HOUSING TUBE SPECIMEN HOLDER SLEEVE

SS-3 TENSILE

PRESSURIZED TUBE AND TRANSMISSION ELECTRON MICROSCOPY (TEM)

SPECIMEN HOLDER

SS-3 TENSILE

REACTOR HORIZONTAL MID-PLANE

HOUSING TUBE

SPECIMEN HOLDER SLEEVE

SS-1 TENSILE

CRACK GROWTH

31.75 cm EXPERIMENT REGION

15.875 cm

42.2 mm I.D. Hf SLEEVE

VERTICAL SECTION THROUGH HFIR-MFE 200J-1 CAPSULE
THE ADVANCED NEUTRON SOURCE PROJECT
TECHNICAL OBJECTIVES

• To design and construct the world's highest flux research reactor for neutron scattering

• To provide isotope production facilities that are as good, or better than, HFIR

• To provide materials irradiation facilities that are as good, or better than, HFIR
THE ADVANCED NEUTRON SOURCE (ANS) REACTOR

- Heavy-water - cooled and reflected
- 364 MW power
- Low coolant water temperature - Inlet 49°C and Outlet 84°C
- Typical fuel cycle length of 14 days
A VARIETY OF MATERIALS IRRADIATION FACILITIES WILL BE AVAILABLE IN ANS (1)

- Fast Neutron Irradiation

  - 5 instrumented and 5 non-instrumented capsule positions are located just inside the upper fuel element

  - The Fast:Thermal ratio may be tuned by about a factor of 3 by selecting different radial positions within the global boundaries of the fast irradiation positions

  - Absolute fast flux increases during burnup as the poison burns and the control rods move, but the absolute value of the Fast:Thermal ratio decreases concurrently.
A VARIETY OF MATERIALS IRRADIATION FACILITIES WILL BE AVAILABLE IN ANS (2)

- Fast/Epithermal Neutron Irradiation
  - Capsules are interchangeable with the transuranium production rods (outside the lower fuel element)

- High Thermal Flux Irradiation
  - Provided primarily by the 2 slant facilities just outside the CPBT in the reflector tank
  - Other in-tank positions are available
CORE AND IRRADIATION FACILITIES

1 m

NON-INSTRUMENTED CAPSULE

UPPER FUEL ELEMENT

INSTRUMENTED CAPSULE

TRANSPLUTONIUM PRODUCTION TARGET

LOWER FUEL ELEMENT

0 m
INSTRUMENTED IRRADIATION CAPSULE (5)

CORE PRESSURE BOUNDARY TUBE

UPPER FUEL ELEMENT (420 PLATES)

NON-INSTRUMENTED IRRADIATION CAPSULE (5)

INNER CONTROL AND SHUTDOWN RODS (4)

OUTER SHUTDOWN ABSORBER CYLINDERS (8)

COLD SOURCE

BEAM TUBE

FJP 8/31
BOC CONDITIONS

FAST-TO-THERMAL RATIO

FAST FLUX

FAST NEUTRON FLUX (N/M²S) \times 10^{19}

RADIAL DISTANCE ACROSS FAST IRRADIATION POSITIONS
EOC CONDITIONS

FAST FLUX

FAST-TO-THERMAL RATIO

RADIAL DISTANCE ACROSS FAST IRRADIATION POSITIONS
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<td>2</td>
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|                                             | 16           | 7               |
|                                             | 20-80        | 4               |
|                                             | 4-10         | 3               |
Fig. 10. Typical Radial Neutron Flux Distributions at Core Horizontal Midplane with Reactor Operating at 100 MW