Annular Core Research Reactor

Operational Overview

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
Abstract

Reactor operations at Sandia National Laboratories, Technical Area Five have been successfully conducted for more than 52 years. Originally, 1964 to 1978, as the Annular Core Pulse Reactor (ACPR) transitioning to and continuing as the Annular Core Research Reactor (ACRR) from 1978 to present. We are allowed steady-state operations up to 4.4 MW and pulse operations not to exceed 60,000 MW. We routinely conduct in excess of 400 operations a year with ~85% of all operations being pulses in the 300 MW to 30 GW range. Recent operational parameters, changes in staffing (loss of operator to engineering, qualification of new operator and licensing of new supervisor), significant maintenance actions (including annual update of our DSA & TSRs), completed improvements (observation cameras, dark room restoration, new compressed air system wide range monitoring system, additional continuous air monitors, better controls of high radiation area, etc.) and planned improvements (reactivity control system upgrade, continuous water sampling system, radiography improvements, etc.) will be reviewed.

Plans continue for conceptual development of a replacement research reactor facility which will utilize the original fuels, uranium zirconium-hydride (UZrH) and uranium dioxide beryllium oxide (UO$_2$BeO). Conceptualization of the new facility includes numerous unique features such as an above ground nuclear island, very large beam ports, a cold neutron source, neutron radiography and continuation of the existing mission. The existing UO$_2$BeO fuel was given a burnup limit of 10% when originally designed in 1977. Over the last 39 years of operation less than 3% burnup has occurred. The validity of the 10% limit is not fully documented and while an extensive post irradiation examination would be elucidating it has not been conducted. Funding the precept of a replacement research reactor facility is dependent on the health of the existing fuel. The fuels health must be carefully evaluated prior to transfer to the new facility. The current state of conceptualization will be reviewed.
SNL TECHNICAL AREA V (TA-V)

Technical Area V

GIF
Aux. Hot Cell
Hot Cell
ACRR
SPR
RML

Technical Area V

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TA-V History

Constructed in 1959 as part of the Nuclear Airplane Project

- Sandia Pulse Reactor (SPR-I) – 1961
- Sandia Pulse Reactor (SPR-II) - 1967
- Sandia Nuclear Assembly Reactor (SNARE) – 1962
- Sandia Engineering Reactor (SER) – 1963
- Annular Core Pulse Reactor (ACPR) 1967
TA-V History

TA-V builds on nuclear reactor success through the ‘70s and ‘80s

- Sandia Pulse Reactor (SPR-III) - 1976
- Annular Core Research Reactor (ACRR) – 1978
- Critical Experiment-Space Nuclear Thermal Power (SNTP-CX) - 1989
- ACRR-Fueled Ringed External Cavity (FREC-II) – 1988
TA-V FACILITIES

Annular Core Research Reactor (ACRR)

Sandia Pulse Reactor (SPR) and Critical Experiments (CX)

Radiation Metrology Laboratory (RML)

Gamma Irradiation Facility (GIF)

Auxiliary Hot Cell Facility (AHCF)

Hot Cell Facility (HCF)

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ACRR Description

- 236 UO$_2$-BeO fueled elements
- 1.5 in (3.8 cm) dia. x 20 in (51 cm)
- 100 g U$_{235}$ per element – 35% enr.

Operating Power level

- 4 MW
- Steady State Mode
- 250 MJ Pulse Mode (6 ms FWHM)
- 300 MJ Transient Mode (Programmable)

Dry cavity 9 in (23 cm) diameter
Extends full length of pool through core

Neutron Flux 4E13 n/cm$^2$-s at 2 MW
- 65% > 1 eV, 56% > 10 keV, 45% > 100 keV

Epithermal Spectrum
Flux in cavity can be tailored for desired energy spectrum (Poly, B$_4$C)

Open-pool type reactor
Fuel elements cooled by natural convection
Pool cooled by HX and cooling tower

FREC-II uses previous ACPR fuel TRIGA type (UZrH) – 20 in (51 cm) dia.
Dry cavity

Fuel burnup is minimal
Reactor used for short duration power runs, pulses, and transients

ACRR CURRENT CONFIGURATION

9” Dry Central Cavity

20” Dry External Cavity

ACRR Core

Fueled Ring External Cavity (FREC-II)
ACRR PULSE OPERATION
236 UO$_2$-BeO fuel elements  
1.5 in (3.8 cm) dia. x 20.5 in (52 cm)  
~100 g U-235 per element

Nominal operating power/energy levels

2.4 MW$_{th}$ Steady-State Mode (license: 3.9 MW)  
10-300 MJ Pulse Mode (6 ms FWHM) (license: 500 MJ)  
400 MJ Transient Mode (Programmable rod withdrawal)

Dry cavity 9 in (23 cm) diameter  
Extends full length of pool through core  
Neutron Flux 4E13 n/cm$^2$-s at 2 MW
ACRR DESIGN CHARACTERISTICS

• Epithermal Spectrum - Flux in cavity can be tailored for desired energy spectrum (Poly, B$_4$C)

• Open-pool type reactor
  Core cooled by natural convection
  Pool water cooled by HX and cooling tower

• FREC-II (fuel ring external cavity) uses previous ACPR-TRIGA type fuel (UZrH) – 184 fuel elements
  Dry cavity 20 in (51 cm) diameter

• Fuel burnup is minimal (<3%)

• Reactor used for short duration power runs, pulses, and tailored transients

• No competitors – No other reactor like ACRR
ACRR ENVIRONMENT CONFIGURATIONS

- Nominal - Free Field (FF) Environment [7.9e12, 1 MeV eq n/cm² per MJ & 7.7 krad γ(Si)/MJ]
- Epithermal Neutron Only – Reduced Gamma LB (Lead Boron) 44” tall or LB36” tall [6.5e12, 1 MeV eq n/cm² per MJ & 1.0 krad γ(Si)/MJ]
- Enhanced Thermal Neutron, Reduced Gamma PLG (Poly/Lead/Graphite), 36” tall [6.6e12, 1 MeV eq n/cm² per MJ & 6.2 krad γ(Si)/MJ]
- No Thermal Neutron, Enhanced Gamma Cd-Poly Cd-Poly (Cadmium/Poly), 26” tall [3.8e12, 1 MeV eq n/cm² per MJ & 12.2 krad γ(Si)/MJ]
- FREC-II Environments – FF, LB, Cd-Poly
POLY/LEAD/GRAPHITE SPECTRUM MODIFIER

**Graphite**
- Density: 1.82 g/cc
- Inner Diameter (ID): 7.25 in
- Outer Diameter (OD): 7.75 in
- Thickness: 0.25 in

**Lead**
- Density: 11.35 g/cc
- ID: 7.75 in
- OD: 8.00 in
- Thickness: 0.125 in
- Melting Point (MP): 327°C

**HDPE**
- Density: 0.945 g/cc
- ID: 8.00 in
- OD: 8.50 in
- Thickness: 0.25 in
- MP: 120°C

**Al 6061**
- Density: 2.7 g/cc
- Inner Thickness: 0.125 in
- Outer Thickness: 0.25 in

Inner and Outer Walls

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NEUTRON/GAMMA ENERGY SPECTRA

Comparison of Free Field to Lead Boron Bucket (LB44)

Free Field

LB44
NEUTRON/GAMMA ENERGY SPECTRA

Comparison of Free Field to Poly-Lead-Graphite Bucket

**Neutron Lethargy Fluence**

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Neutron Lethargy Fluence per MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-10}$</td>
<td>0.0</td>
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<tr>
<td>$10^{-9}$</td>
<td>$1.0e+12$</td>
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<tr>
<td>$10^{-8}$</td>
<td>$2.0e+12$</td>
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<tr>
<td>$10^{-7}$</td>
<td>$3.0e+12$</td>
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<tr>
<td>$10^{-6}$</td>
<td>$4.0e+12$</td>
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<tr>
<td>$10^{-5}$</td>
<td>$5.0e+12$</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>$6.0e+12$</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>$7.0e+12$</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>$8.0e+12$</td>
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<tr>
<td>$10^{-1}$</td>
<td>$9.0e+12$</td>
</tr>
<tr>
<td>$10^0$</td>
<td>$1.0e+13$</td>
</tr>
<tr>
<td>$10^1$</td>
<td>$1.2e+13$</td>
</tr>
</tbody>
</table>

**Prompt Gamma Ray Energy Fluence per MJ**

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Prompt Gamma Ray Energy Fluence per MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-3}$</td>
<td>0.0</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>$2.0e+12$</td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>$4.0e+12$</td>
</tr>
<tr>
<td>$10^0$</td>
<td>$6.0e+12$</td>
</tr>
<tr>
<td>$10^1$</td>
<td>$8.0e+12$</td>
</tr>
<tr>
<td>$10^2$</td>
<td>$1.0e+13$</td>
</tr>
<tr>
<td>$10^3$</td>
<td>$1.2e+13$</td>
</tr>
</tbody>
</table>

**Free Field**

**PLG**

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ACRR has been used in many experiment programs over the years

– Weapon Component Testing – Our original and continuing mission
– Radiation Effects Science – New methods based on recent discovery
– QASPR – Qualitative Alternatives to SPR
– Fast Reactor Safety – CRBR, Advanced fuel/cladding testing, equation of state
– Light Water Reactor Safety – TMI, Severe fuel damage and fission product release from debris beds
– Nuclear Pumped Laser (FALCON) – Part of Reagan’s Star Wars Defense
– Space Thermal Nuclear Power (SNTP) – Critical experiments, particle fuel testing, element testing using hydrogen
– Medical Isotope Production (Mo-99, I-125) – Domestic production initiative
Transition phase studies in LMFBR pin arrays (TRAN Program - JNC, NRC)

Pin heatup, clad melt and FP release, and fuel disruption sequence in LMFBR high burnup fuel pin (FD Program - JNC, UKAEA, KFK, NRC)

Axial clad and fuel relocation in LMFBR pin array (STAR Program - JNC, NRC)

Severe fuel damage and FP release tests on LWR fuel bundle (SFD Program)

ACRR has been used to simulate a wide range of transient fuel test conditions
A study team formed in September 2010 at the request of the Strategic Customer Partnership, Nuclear Weapons (NW) Program Office.

They were to conduct an independent, objective evaluation of NW mission needs and compare available alternatives to perform those functions currently accomplished at ACRR.

This study was not a design effort.

The illustrative design presented was for pre-conceptual evaluation.

And We’re Still looking for a great facility name.
EXISTING FACILITY
REPLACEMENT FACILITY APPROACH

After it was determined that a continuing need existed a detailed multi-day workshop, with external and internal participants, met to answer the following questions:

• What are the NW Mission needs in development, qualification and surveillance for the next 15 years?
• What will the long term NW Mission needs for greater than 15 years and why?
• What are the Non-NW Mission needs for the other TA-V Nuclear Facilities and why?
• What additional capabilities would you want in a new Nuclear Facility and why?
NEW FACILITY CONCEPTUALIZATION

Goals of the New Facility

• Establish a capability that meets all current safety standards for nuclear facilities
• Design Safety & Security into the facility
• Consolidate the two existing nuclear reactor facilities into one facility with common utilities and support systems
• Develop state-of-the-art research reactor experimental facilities, critical assembly facility and criticality safety training capability
NEW FACILITY DESIGN INTENT

• Maintain the existing fuel and operational capabilities of ACRR (<60 GW, <500 MJ, <7 ms pulse width, ~ 8E12 neutrons/cm² per MJ)

• Allow testing of Category II (none currently identified) or Category III Special Nuclear Material

• Fulfill the mission needs for testing of nuclear weapons electronics with high reliability

• Implement badly needed technical improvements and increase operational efficiencies

• Support non-weapons research and development program work

• Reduce radiation exposure to personnel
<table>
<thead>
<tr>
<th>Facility</th>
<th>Power</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRAD (Idaho)</td>
<td>150 kW</td>
<td>No Pulse, TRIGA, 11’ pool, Neutron Radiography, Small Sample Irradiation</td>
</tr>
<tr>
<td>FFTF (Hanford)</td>
<td>400 MW</td>
<td>Cold Standby</td>
</tr>
<tr>
<td>ATR* (Idaho)</td>
<td>250 MW</td>
<td>No Pulse, 4’X5” Static, Rabbit (.5”X2.1”), “Small Amount” of Fissile</td>
</tr>
<tr>
<td>ATRC* (Idaho)</td>
<td>5 kW</td>
<td>No Pulse, Worth Measurements for ATR</td>
</tr>
<tr>
<td>LACEF (Nevada)</td>
<td>&lt; 1 kW</td>
<td>Flattop/Planet/Comet, Critical Exp.</td>
</tr>
<tr>
<td>LA Godiva (Nevada)</td>
<td>1 kW</td>
<td>Fast Burst, Bare Metal</td>
</tr>
<tr>
<td>HFIR* (ORNL)</td>
<td>85 MW</td>
<td>No Pulse, 4 Beam Tubes &amp; In-Core</td>
</tr>
<tr>
<td>WSMR (New Mexico)</td>
<td>10 kW</td>
<td>Fast Burst, Bare Metal</td>
</tr>
<tr>
<td>TREAT (Idaho)</td>
<td></td>
<td>In Restart (Last Operation 1994)</td>
</tr>
<tr>
<td>MIT Reactor*</td>
<td>5 MW</td>
<td>No Pulse</td>
</tr>
<tr>
<td>NC State (Pulstar)*</td>
<td>1 MW</td>
<td>No Pulse</td>
</tr>
</tbody>
</table>

*DOE National Scientific User Facility
NEW FACILITY CONCEPTUALIZATION

- Enhance experimental flexibility and effectiveness
- Utilize existing designs for reactor fuel, core grid, central cavity, large-diameter external cavity and neutron radiography thermal beam tube
- Additional reactor facility capabilities
  - Beam ports, pure neutron beams, activation analysis (PGAA), and tailored pulses
  - Movable core within the reactor tank
  - Integral hot cell for fuel maintenance and higher dose rate experiments
  - Offset loading tube, shuttle & pneumatic rabbit system
NEW FACILITY CONCEPTUALIZATION

• Technical improvements
  – Better data from experiments (lower electronic noise), more measurement fidelity
  – Enhanced neutron radiography (resolution, quality, and dynamic image capture)
  – High intensity cold neutron source (HFNRF-II)
• Improved flows and efficiencies allow for higher workloads
• Overhead crane services experiment which can weigh from a few pounds to a ton or more.
• Secure package transport
NEW FACILITY CONCEPTUALIZATION

• Integrated facility with support functions and office space in close proximity
• All other facilities on site would be decommissioned
• ACRR Operations would be continued until 6 months before fuel transfer
• Fuel would be evaluated (after cooldown) and then transferred to the new facility
• Design anticipated to begin in the next 5 years
• From initial design to initial criticality will be ~ 8 years
ABOVE GRADE NUCLEAR ISLAND
CONCEPTUAL LAYOUT
Questions?