Idaho Operations Office

# Beryllium and the Advanced Test Reactor (ATR) Background and Research Presentation to National Academy of Sciences August 29, 2007

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# Summary

- Advanced Test Reactor
- Beryllium Background
- Current Status
  - Supply
  - Waste Disposition
  - To Date Research Efforts
- Research Needs
  - Pre Irradiation
  - Post Irradiation

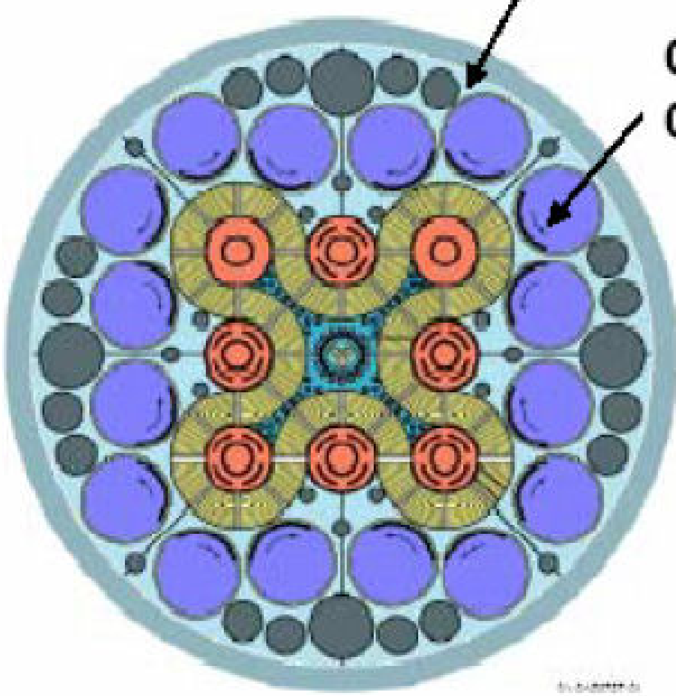
# Advanced Test Reactor (ATR)

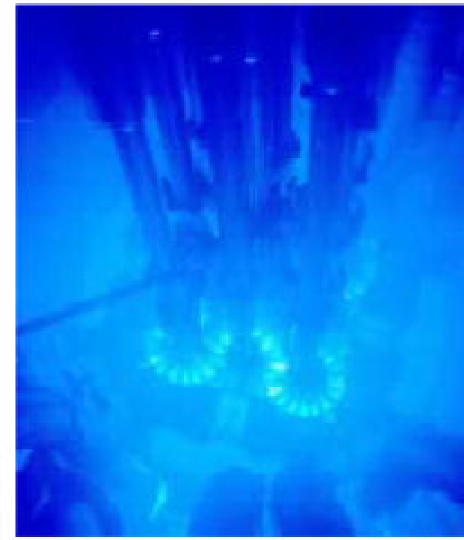
- Started Operations in 1967
- High Thermal Neutron Flux makes the ATR desirable for testing materials
  - Larger number of neutrons seen by test materials than under normal reactor operations
- Primary mission was to research and test Materials and Fuels for the Nuclear Navy
  - Research into reactor core components have significantly extended the life of Navy reactors
- Additional mission for Materials and Fuels research and Isotope Production for other uses added later

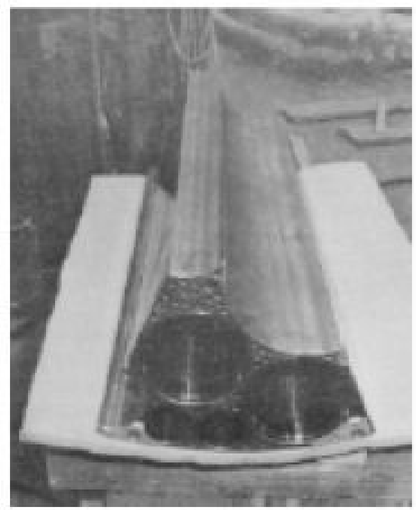
# Beryllium Background

- Used in Nuclear Weapons, Defense Needs, Optics, Non Sparking Tools, breeding blankets for fusion reactors, and Fission Reactor components
- Used in ATR as a reflector material that allows the reactor Thermal Neutron Flux to be concentrated
- ATR has 8 reflector blocks and 16 outer shim control cylinders (OSCC) made from Beryllium
- Contains trace amounts of other elements that includes:
  - Lithium
  - Uranium (10 – 70 PPM)
  - Iron
  - Cobalt
  - Nitrogen

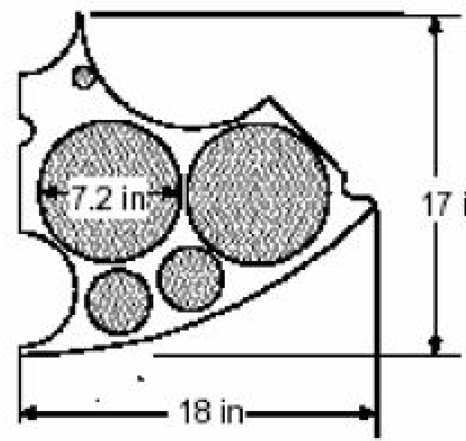
# Beryllium Background (Cont.)





Reflector Block



# Beryllium Background (Cont.)

- Upon irradiation, material produces
  - Entrapped Tritium gas that causes reflectors and outer shim control cylinders to swell and crack
  - Every 8 to 10 years, reflectors and OSCC are replaced in a Core Internals Changeout (CIC) due to swelling / cracking
  - Transuranic Waste (>100 Nanocurries per Gram)
  - Other radioisotopes make disposal a significant problem (Carbon 14, Cobalt 60, Tritium)

# Beryllium Background (Cont.)

- Beryllium was disposed at Radioactive Waste Management Complex (RWMC) in Idaho
- Beryllium components stored in ATR canal due to high radiation field from Cobalt 60
- Prior to 2001 was disposed as metal
  - Beryllium is soluble in groundwater
  - Released entrapped Tritium and caused plume
  - Have tried to encapsulate older disposed Beryllium with little success
- In 2001, discovered the trace Transuranic elements

# Current Status

- Beryllium declared as Waste with “No Path to Disposition” in 2004 and required path prior to next CIC
- Added to Greater Than Class C (GTCC) Environmental Impact Statement (EIS) Notice of Intent inventory to provide path
- Supplier (Brush Wellman) shutdown Ore Concentration (Pebble) Plant and building new facility
- Limited research on Beryllium supply, waste disposal and recycling
  - Working with International Consortium that includes Japan and Russia

# Supply

- All US Beryllium contains enough uranium to create transuranics
- Brush Wellman is building new facility as cost share with DOD as a Title 3 Defense Production Act project
- Drawing down from Defense National Stockpile until new facility built
- DOE has coordinating committee for supplying DOE needs
- Lower Uranium content Beryllium being procured from Kazakhstan
  - High iron content makes it hard to machine and being with current US supplies
  - Still not low enough uranium content to not produce transuranics

# Waste Disposition

- Upon irradiation the Beryllium reflectors and OSCC generate
  - Transuranics from uranium
  - Tritium from Lithium and Beryllium
  - Carbon 14 from Nitrogen
  - Cobalt 60 from Cobalt and Iron
- Can be classified as Transuranic Waste (DOE) or Greater Than Class C (NRC)
  - Requires Geological Depository for Disposal
- Waste must be Remote Handled due to radiation field from Cobalt 60, 30 years wait time for lower field
- Developing a Disposition Steering Committee with DOE-EM

# Waste Disposition (Cont.)

- RWMC
  - Can not dispose transuranics
- WIPP
  - Consumes WIPP Radiological Inventory with Tritium and Carbon 14
- Yucca Mountain Complex (YMC)
  - Currently only authorized for Commercial Spent Nuclear Fuel
- Greater Than Class C EIS Notice of Intent
  - Evaluate options for disposal includes WIPP, YMC or other locations

# To Date Research Efforts

- Separations / Dissolution of Transuranics
  - Limited research in Idaho and Russia
  - Waste generated still problematic
- Heat Treatment to remove Tritium
- Low Uranium Beryllium
  - Need 1 to 2 PPM Uranium to not generate transuranics
  - Brush Wellman developed potential process, cost is prohibitive
- Low Nitrogen (Carbon 14 generation)
  - Brush Wellman developed process

# Research Needs

- Working with Russia and Japan on Beryllium issues through the International Science and Technology Center (ISTC) (US State Dept.)
- Pre Irradiation to not generate problematic waste
  - Low Uranium content
  - Low cobalt and iron content
  - Strengthening/Stiffening
- Post Irradiation for recycle and disposal
  - Separations / Dissolution
  - Recycling
  - Waste stabilization
  - Waste encapsulation

# Pre Irradiation

- Low Uranium
  - Low volume makes capital improvements costly
  - Still have to deal with historical waste issues
- Strengthening/Stiffening
  - Improve the strength and stiffness to prevent or slow down swelling / cracking
  - Potential life extension of Be components in reactor
  - Potential research in Japan and Russia under ISTC

# Post Irradiation

- Separations / Dissolution
  - Chlorine Gas ($Cl_2$) process development by ISTC
    - Heated $Cl_2$ below Be melting point reacts with Be to form BeCl gas
    - Gas leaves behind salts and radioisotopes
    - Gas then heated to 1450 C and Cl disassociates
    - Be drops from gas – potential for recycle
  - No ongoing research on Dissolution process
  - Waste generated by both $Cl_2$ gas and Dissolution needs research

# Post Irradiation (Cont.)

- Recycling
  - Be from $Cl_2$ gas or dissolution could be reused
  - Potential for use in breeder blankets for Fusion reactors
  - No ongoing research for recycling
- Waste Stabilization
  - Create Be silicates or phosphates like natural ores to stabilize for disposal (metal reactive in groundwater)
    - Potential to use vitrification process to create Be silicates and drive off Tritium
  - Waste form potentially less than TRU and GTCC limits

# Post Irradiation (Cont.)

- Waste Stabilization (Cont.)
  - Different waste streams from all processes need research on stabilization (Cl2 gas, dissolution)
  - Thermal treatment to remove/capture Tritium
- Waste Encapsulation
  - Current buried waste needs better waste encapsulation to prevent Tritium plume
  - Stabilized waste forms may need encapsulation for entrapped radioisotopes

# Review

- Current Status
  - Supply
    - No Ore Concentration facility and drawing down Defense National Stockpile
  - Waste Disposition
    - Classified as TRU and GTCC
    - GTCC EIS Notice of Intent
    - Developing Disposition Steering Committee with DOE-EM
  - To Date Research Efforts
    - Low Uranium and Nitrogen Beryllium
    - Heat Treatment for Tritium removal
    - Dissolution

# Review

- Research Needs
  - Pre Irradiation
    - Low Uranium capital costs
    - Strengthening / Stiffening for life extension
  - Post Irradiation
    - Separations / Dissolution ($Cl_2$ gas, dissolution)
    - Recycling
    - Waste Stabilization (silicates, phosphates)
    - Waste Encapsulation