Depleted Uranium Applications in Geological Repositories

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Depleted Uranium Workshop
U.S. Department of Energy, Russian Academy of Sciences,
State Unitary Enterprise, and Russian Research Institute of Chemical Technology
Moscow, Russia
Spring 2002

*Managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725. The submitted manuscript has been authored by a contractor of the U.S. Government under contract DE-AC05-00OR22725. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes. File name: Moscow.cermet.2001.

Outline

- Strategic Vision
- Applications of Depleted Uranium (DU) in a Geological Repository
- Repository Benefits
- Research and Development Issues
- Conclusions

Strategic Vision: Repository Applications Can Beneficially Use All the DU While Maintaining Future Options

- Repository applications ensure safe disposal of DU as a waste
- DU can improve the operations and long-term performance of the repository system (transport, storage, and disposal)
- Use of DU for spent nuclear fuel (SNF) disposal co-locates fissile and fertile materials so that recovery is possible—if required by future generations for energy production

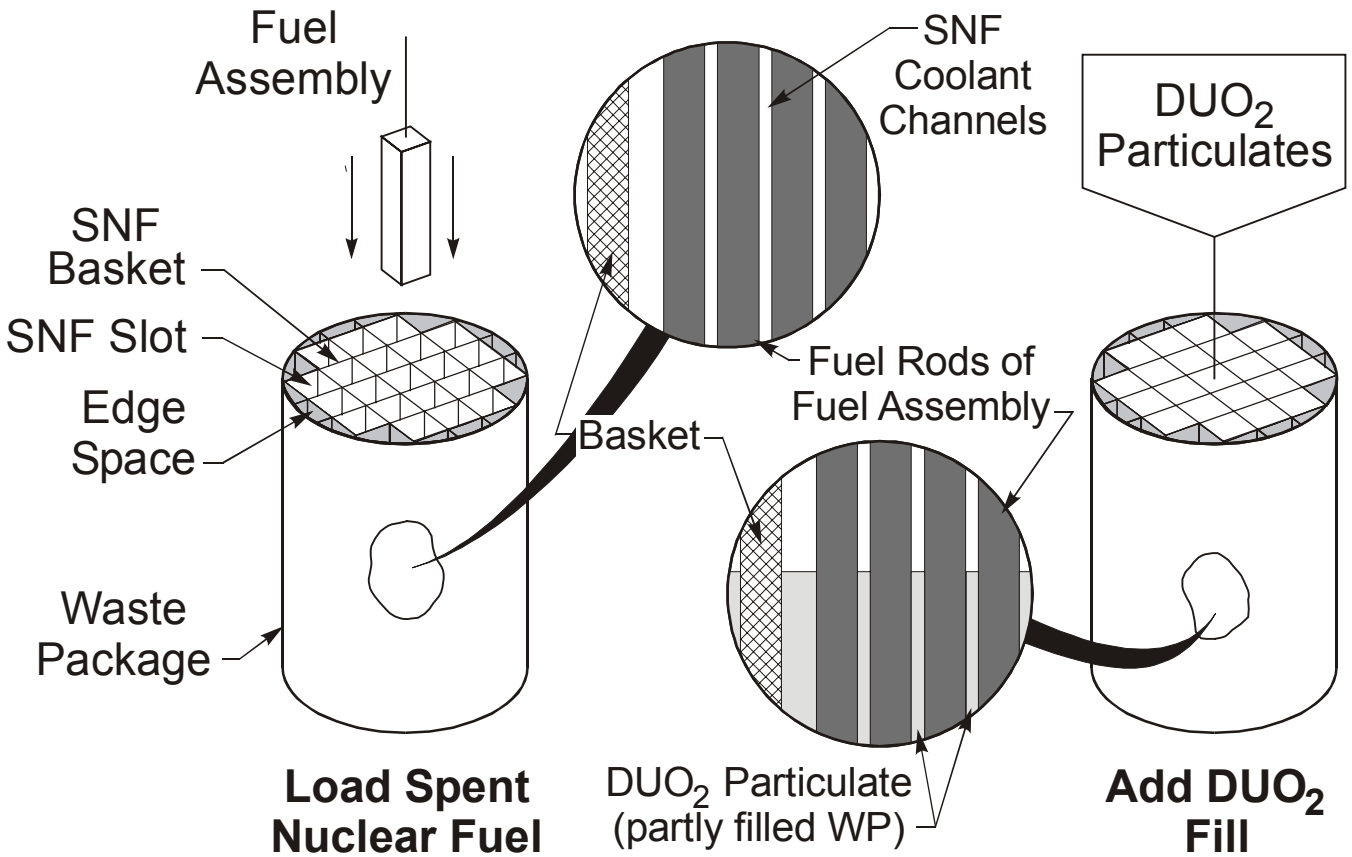
Program (Mission) Objectives

- Develop the technology for DU applications in the repository system
- Address institutional issues regarding DU use for repository system applications
  - Licensing (controls many design features)
  - Public acceptance
- Understand the economics of DU repository applications

Repository Applications

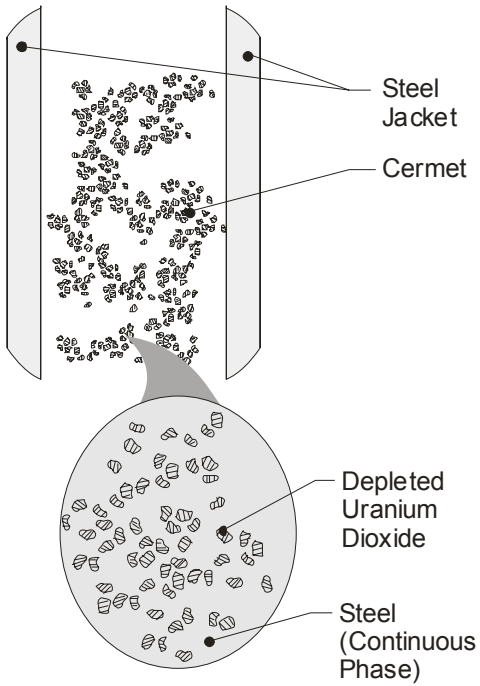
DUO_2 Particulate Fill
Cermet Waste and Multipurpose Packages

DUO_2 Particulate Fill Can Be Added to SNF Waste Packages (3–4 kg DU/kg SNF)

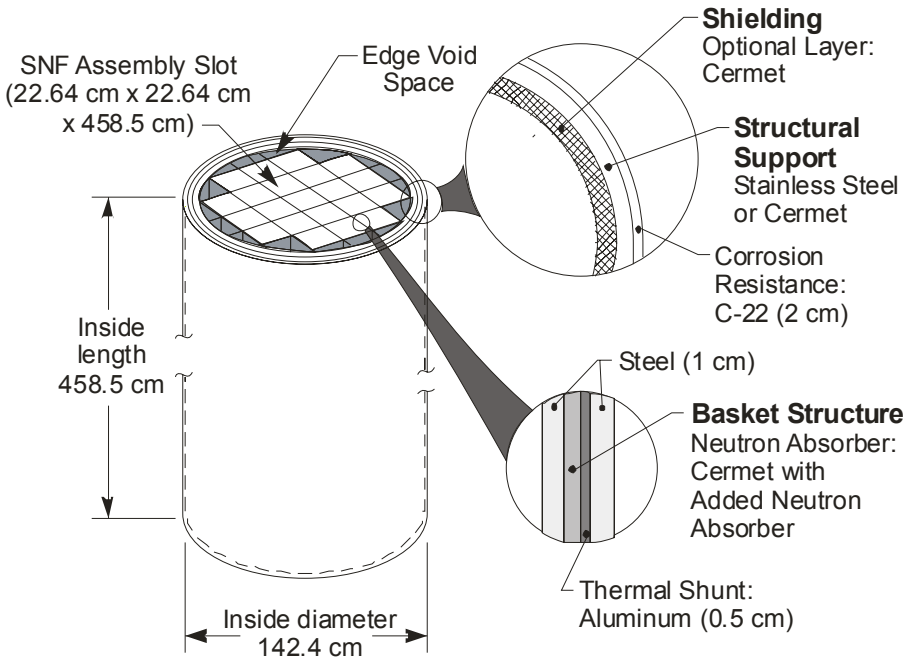


Waste and Multipurpose Packages Can Be Constructed of a DUO_2-Steel Cermet (3-8 kg DU/kg SNF)

Cermet



Applications



Repository Benefits of Using DU

Shielding

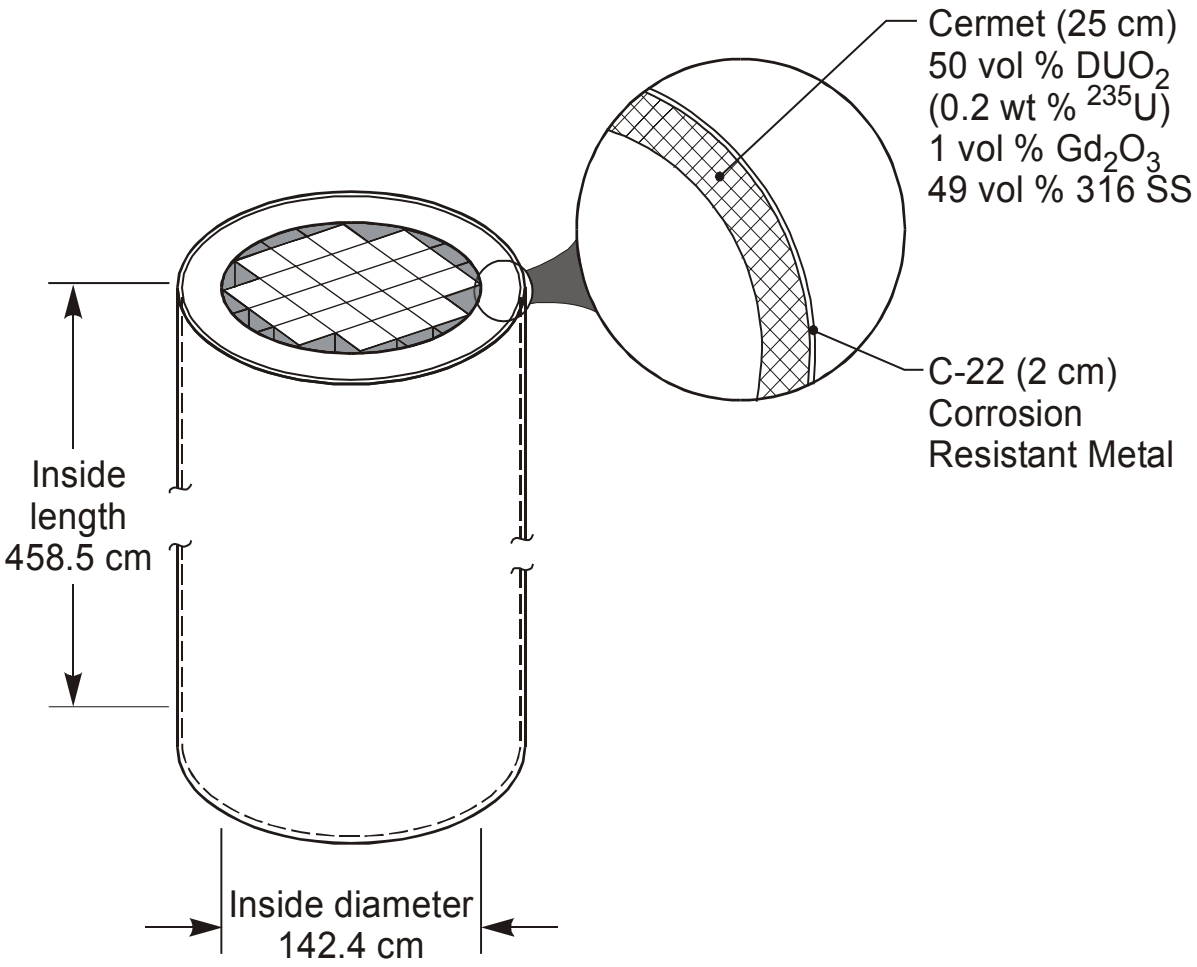
Prevention of Repository Criticality

Reduced Radionuclide Release Rate

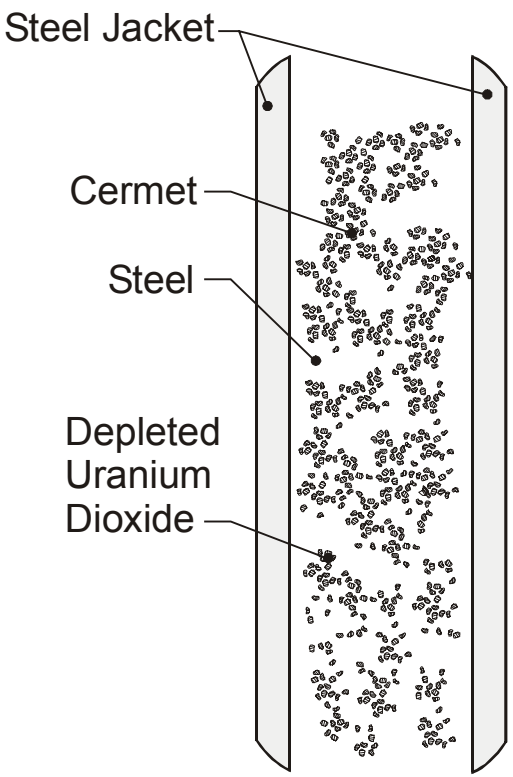
Preservation of Waste Package Geometry

Shielded Waste Packages Can Be Made of a DU Cermet—DU Use Without Impacting Operations

(Example: Shielded Yucca Mountain Waste Package)

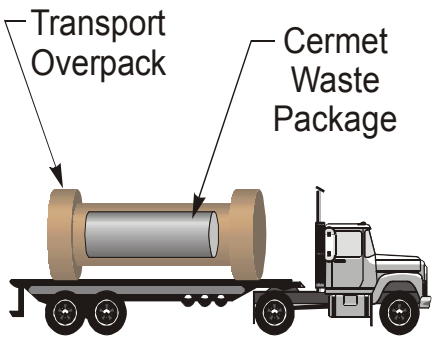


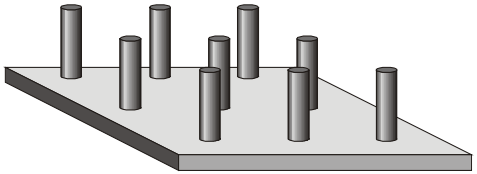
Cermets Are Good Shielding Materials with Some Unique Capabilities

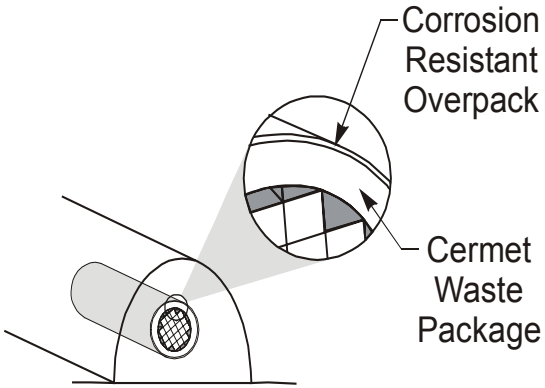


- Gamma Shielding Better Than Steel
  - Steel: 7.86 g/cm^3
  - DUO_2: 10.9 g/cm^3
- Neutron Shielding
  - High-density oxygen (DUO_2) moderator
  - Other neutron absorbers can be added
- Good Physical Properties
  - High thermal conductivity
  - No organics (no fire; acceptable to repository)

DU Cermet Waste Packages Create the Option of a Multipurpose Cask System
(Inner Cermet Package with Different Overpacks)







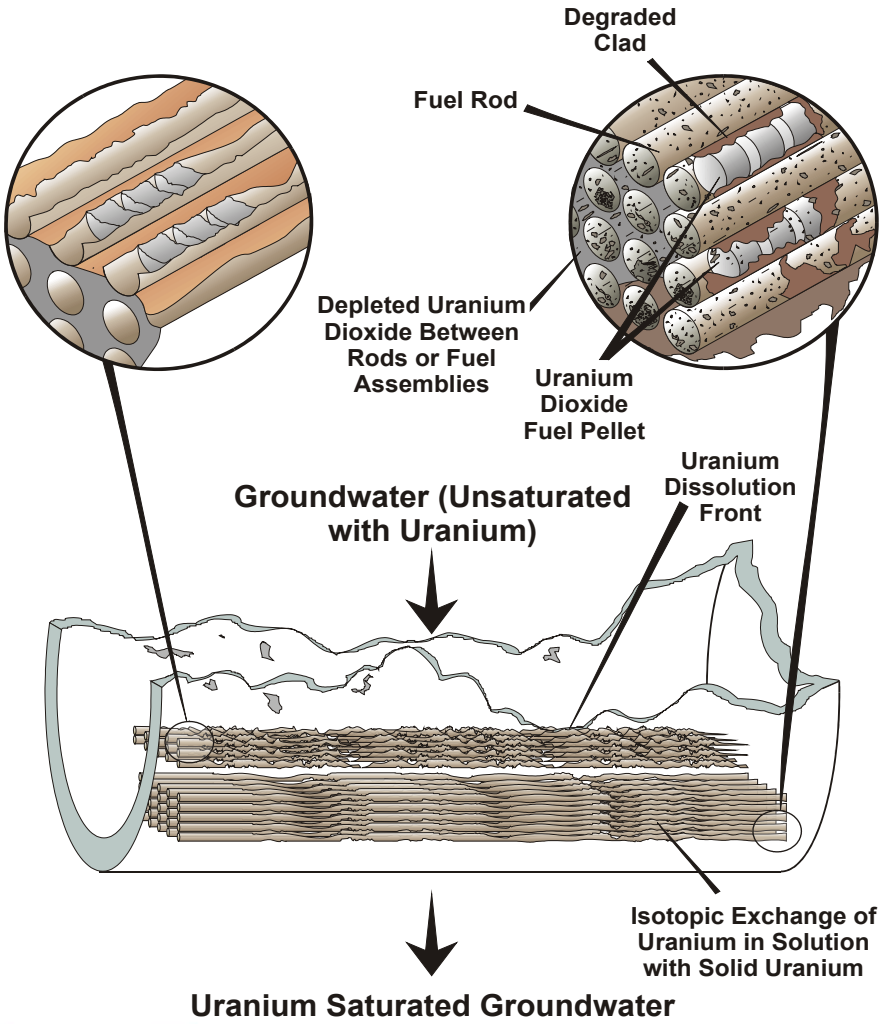
Transport from Reactor

Storage

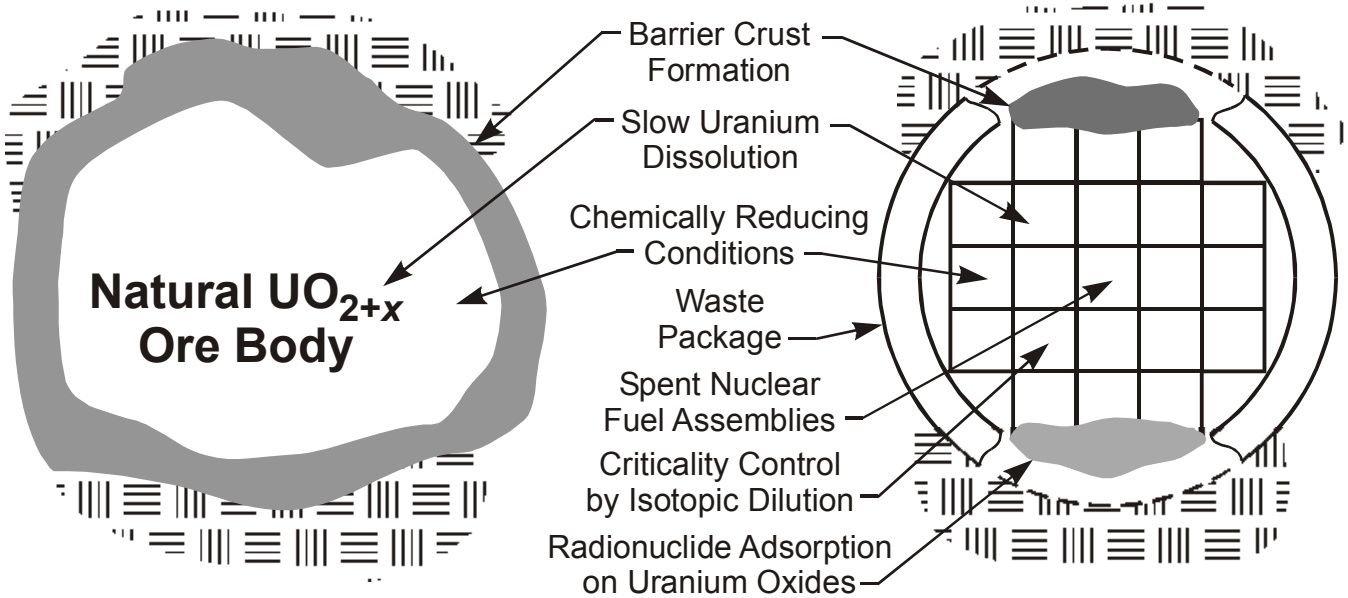
Disposal

Long-Term Repository Criticality Control Can Be Ensured by Adding DU (Fill or Cermet) to Waste Packages

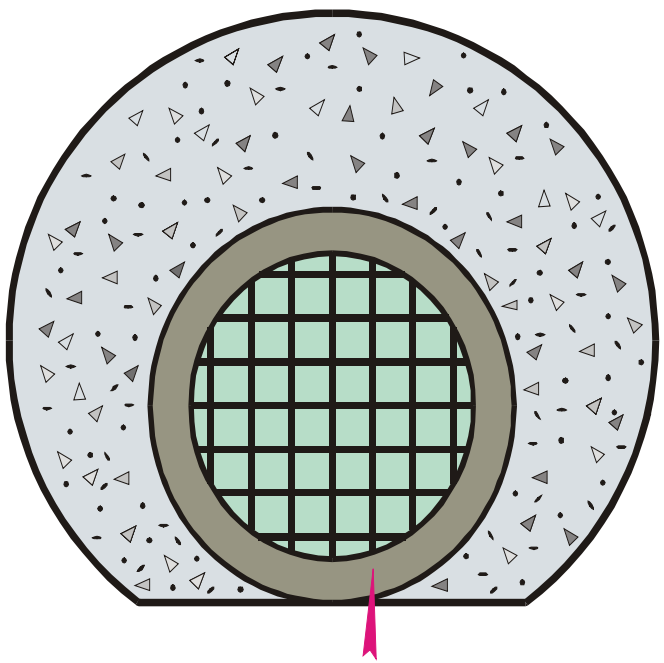
(Isotopic Mixing Occurs as Package Degrades)



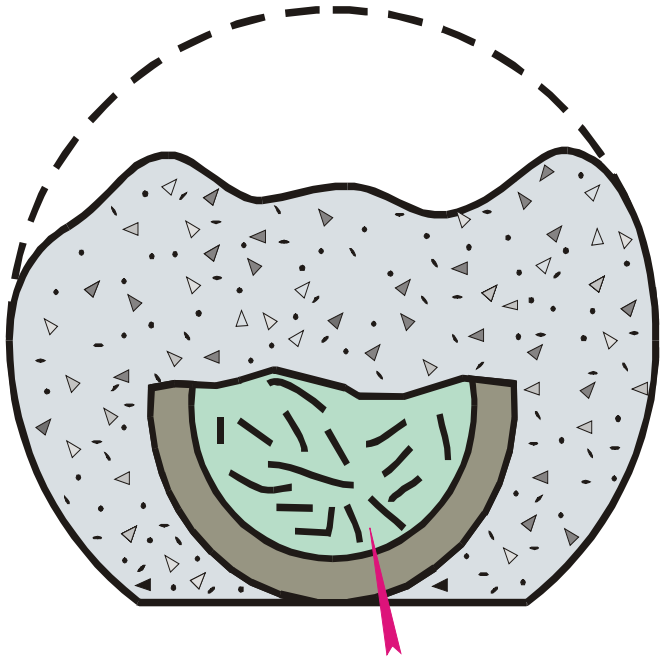
Some Uranium Ore Deposits Have Remained Intact for Millions of Years: The Same Mechanisms Should Protect SNF in Waste Packages Containing DUO_2



Fills Provide Internal Support That Delays Waste Package Collapse with Loss of Barriers Against Radionuclide Releases



Intact Waste Package
or Waste Package with Fill
(High Resistance to Collapse)



Failed Waste Package
(Collapse With No
Internal Support)

Potential Areas of Cooperative Research and Development

- Repository performance
  - A few radionuclides (Np and Tc) dominate radionuclide releases from the repository
  - Preliminary data suggest hydrated uranium oxides delay release of key radionuclides from the waste package and repository
  - More experimental data are required
- Lower-cost cermet production techniques
- Fill behavior over geological time

Conclusions

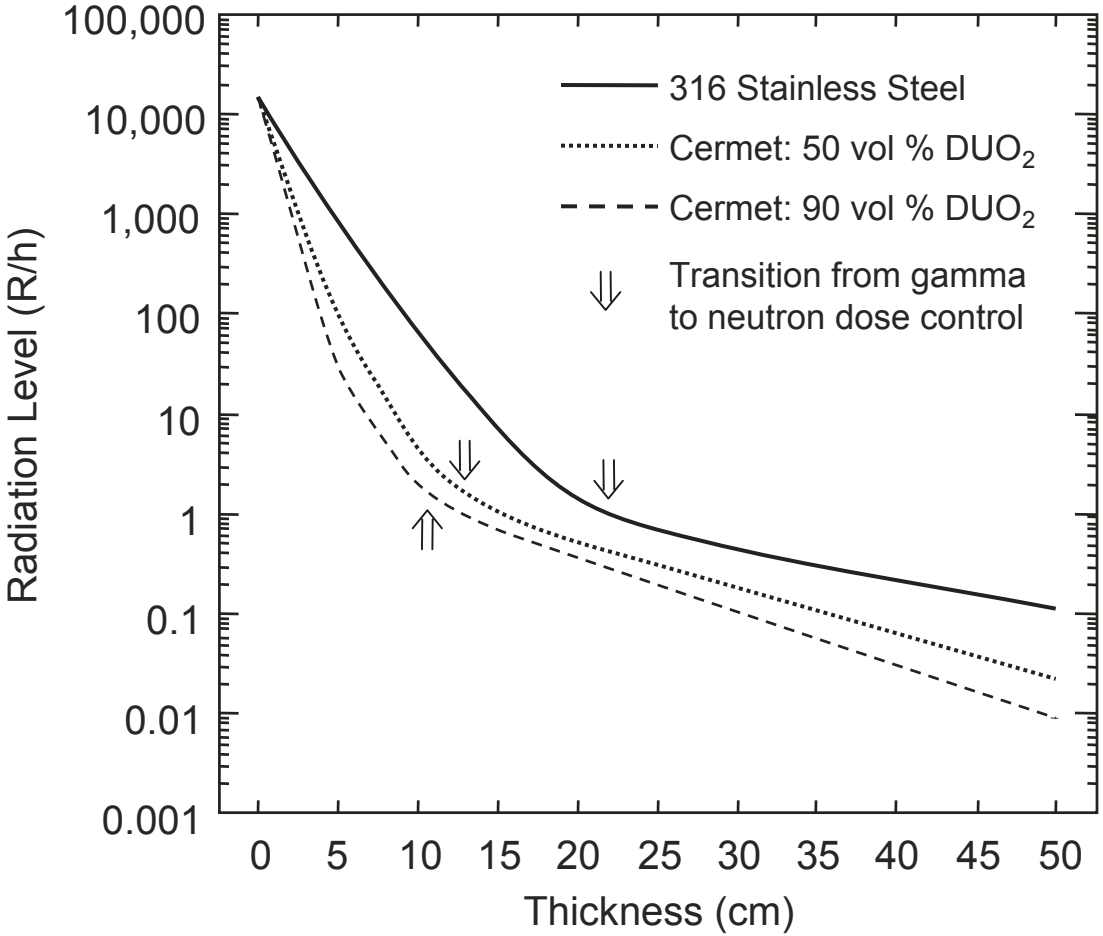
- DU can be used in multiple applications within a geological repository system
- There are many advantages
  - Shielding (including multipurpose canister)
  - Improved repository performance
  - Disposal of excess DU
- Several areas of R&D have been identified
  - Sorption of radionuclides on uranium oxides
  - Cermet-manufacturing techniques
  - DUO_2 bed behavior

Additional Information

Sandwich Construction of Cermets

- Radioactive uranium is contained by exterior steel layers (no contamination)
- Construction maximizes strength—with strongest components on the outside, offering accident and sabotage protection
  - Interior steel layer
  - Cermet
  - Exterior steel layer

Shielding Effectiveness (R/h) of Different Materials
(Source Term from 21-PWR Yucca Mountain Waste Package)



Incentives Are Increasing for the Use of Multipurpose (Storage, Transport, and Disposal) SNF Casks

- **Multiple types of savings are possible**
  - Capital cost savings by using one cask for three applications
  - Operational cost and safety advantages by avoiding multiple transfers of SNF
- **Changing conditions may favor multipurpose SNF casks**
  - Requirements for storage, transport, and disposal casks are becoming more similar as accident and sabotage protection requirements increase
  - The better definition of repository requirements allows for design of multipurpose casks that are usable for disposal
  - New technologies enable the design of casks to more easily meet multiple requirements

An Example Configuration of a Cermet Multipurpose Cask

- Cermet cask functions
  - Shielding
  - Accident and sabotage protection
  - Criticality control
- Cask system components
  - Dry storage: cermet cask
  - Transport: cermet cask plus transport overpack
  - Disposal: cermet cask plus repository overpack
    - Overpack is a corrosion-resistant outer package
    - U.S. overpack is a 2-cm-thick C-22 (high-nickel/chrome alloy) package

Cermets May Be the Best Shielding Material for Multipurpose Casks

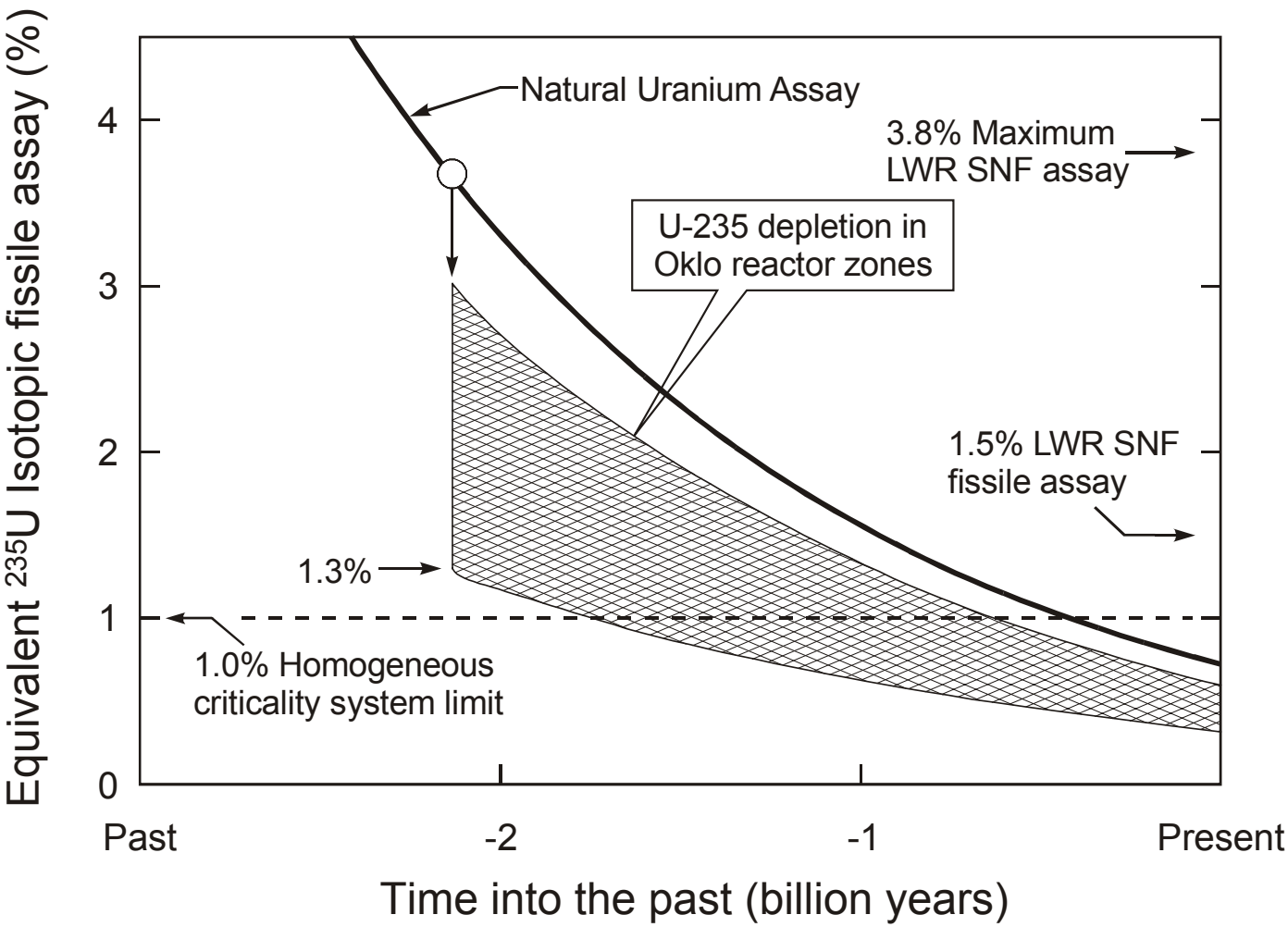
(Excellent gamma shielding; moderate neutron shielding)

- Strong incentives for good shielding materials
  - Cask weight and size limits at reactor
  - Larger size cask increases repository tunnel diameters
- Each application has different requirements
  - Dry storage at reactor or repository
  - Transport
  - Disposal
- In the United States, non-shielding cask requirements eliminate many possible shielding materials of construction
  - Avoid costly materials (tungsten, etc.)
  - Avoid heavy metals (lead, cadmium, etc.)
  - Avoid potential long-term repository performance degradation (concrete, organics, metallic uranium)

Depleted Uranium in Waste Packages Can Minimize Long-Term Repository Nuclear Criticality

- Fissile assay of commercial SNF is about 1.5 wt % ^{235}U equivalent
- Natural reactors (Oklo, Gabon) have occurred at uranium assays of ~1.3 wt %
- Addition of DU is a practical means of decreasing the fissile content to ensure post-closure criticality control

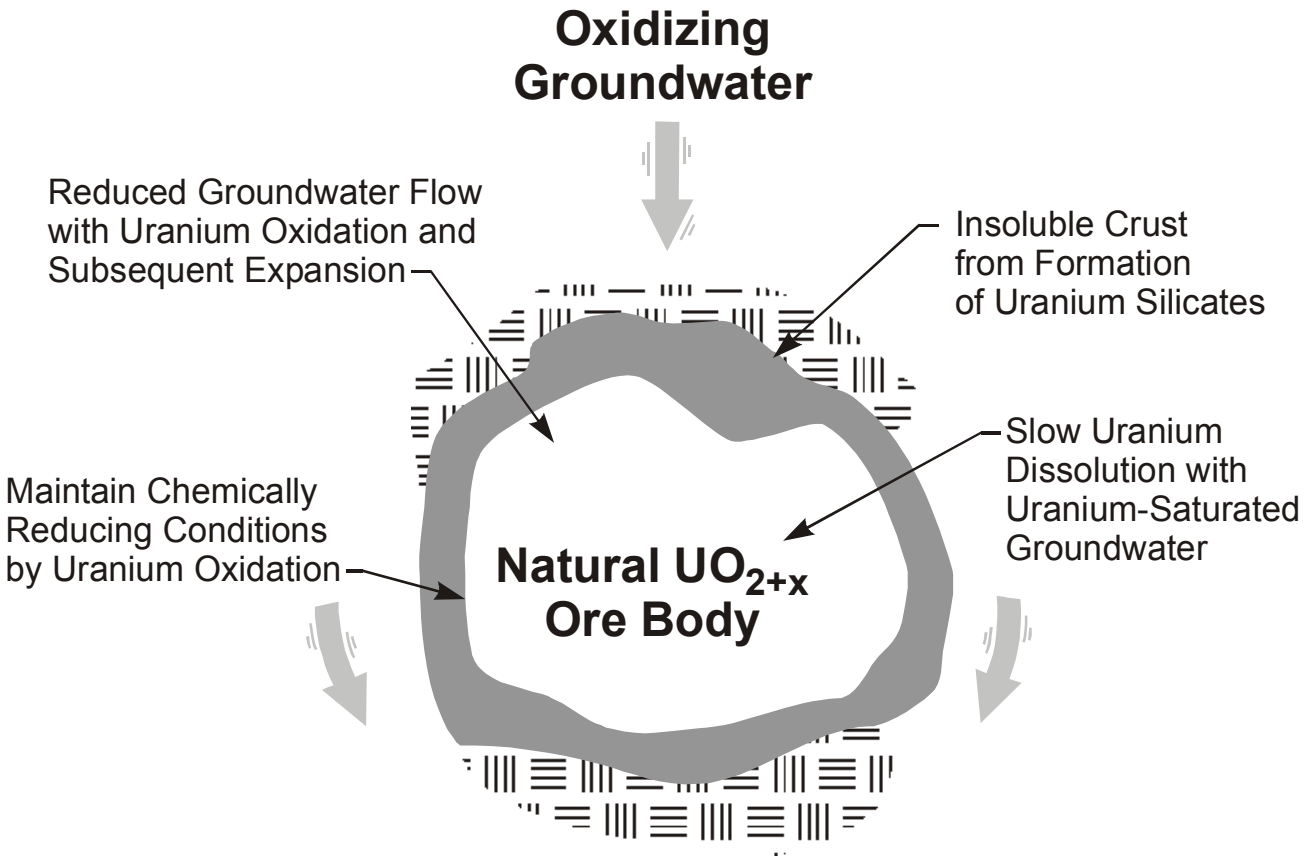
Nature Has Created Nuclear Reactors When the Fissile Assay Exceeds 1.3 wt % ^{235}U Equivalent



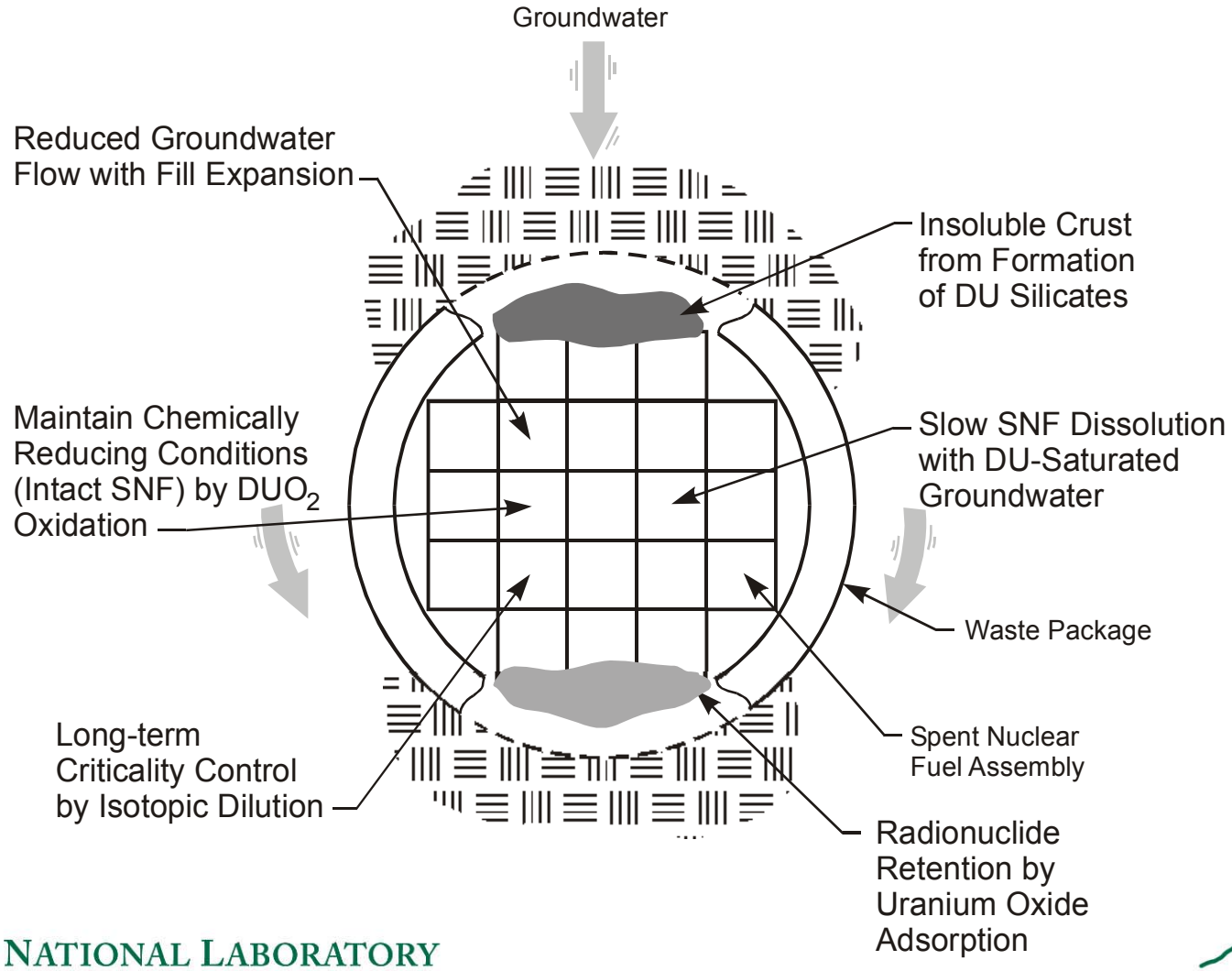
In Repository Systems, Cermets Have Advantages When Compared with Uranium Metal

- Cermets have better long-term (>10^3 years) properties
  - Corrosion resistance
  - Geochemical behavior
- Cermets have potentially lower costs
  - Conversion to DUO_2 is less expensive than conversion to DU metal
  - Properties can be modified for application

Interiors of Natural Uranium Ore Deposits Are Preserved for Extended Times by Degradation of Uranium Oxides on Outside Surfaces of Deposits



Waste Package with DUO_2 Can Use the Same Mechanisms To Help Preserve SNF



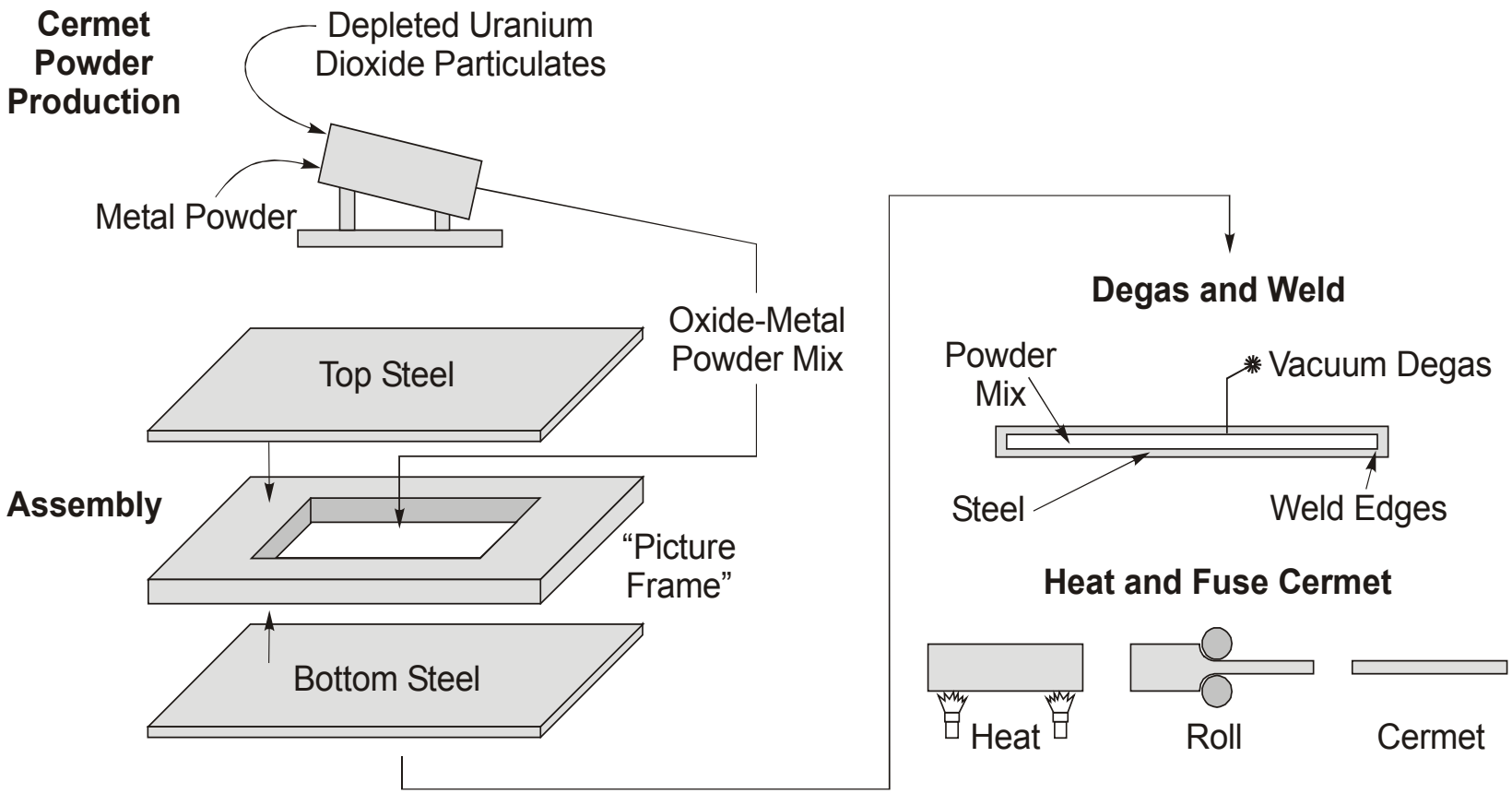
Techniques for Manufacturing Cermets

"Picture frame" (historical approach for UO_2 cermets)

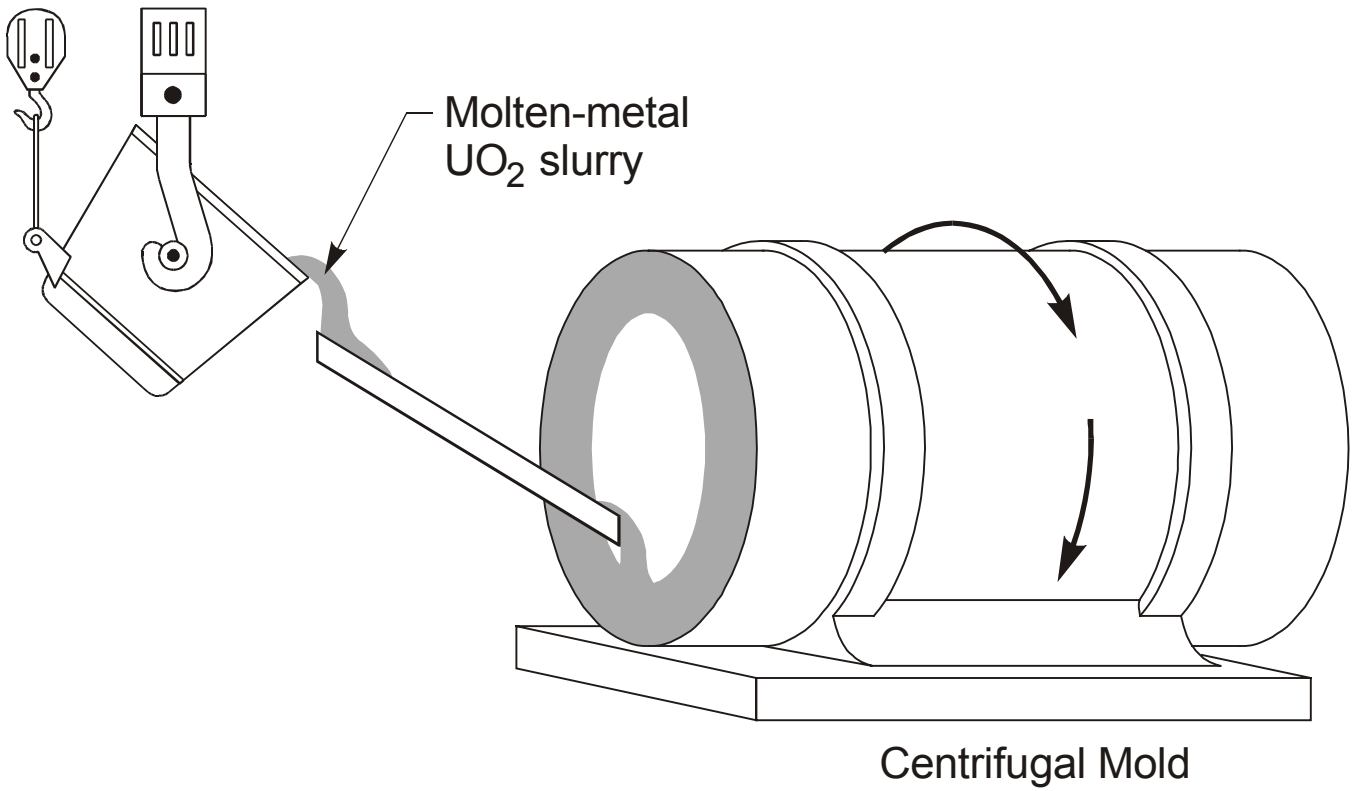
Spin casting (future option)

"Picture-Frame" Method for Cermet Production

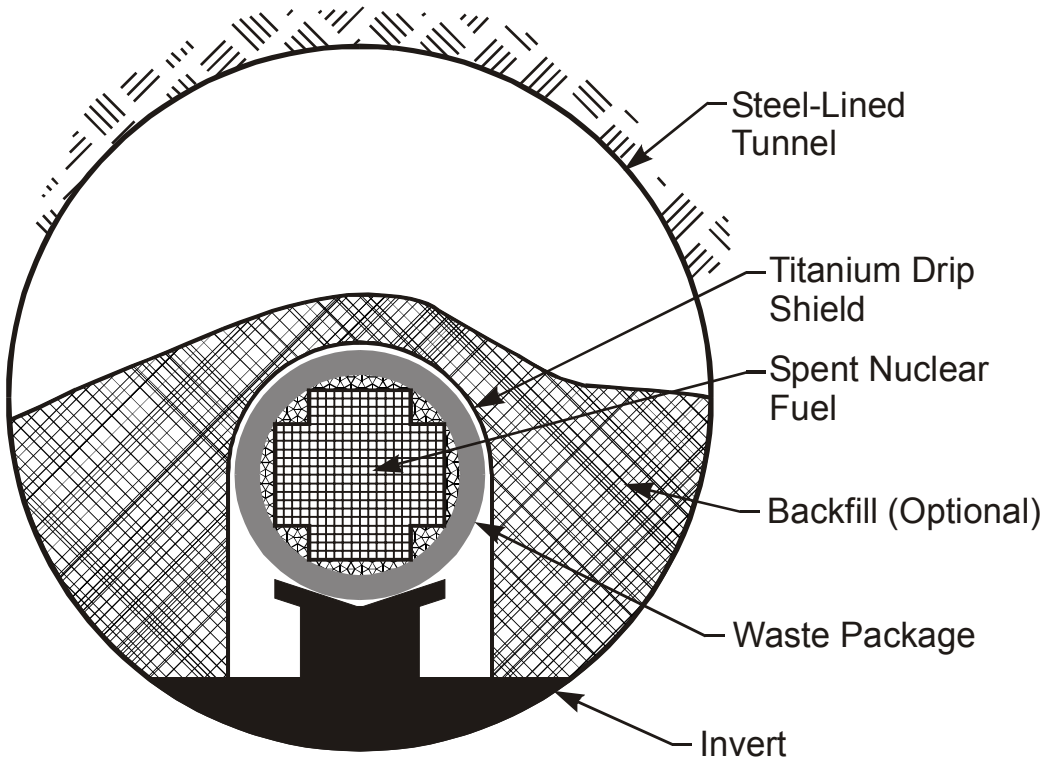
(Used for Some Nuclear Reactor Fuels and Some Nonnuclear Applications)



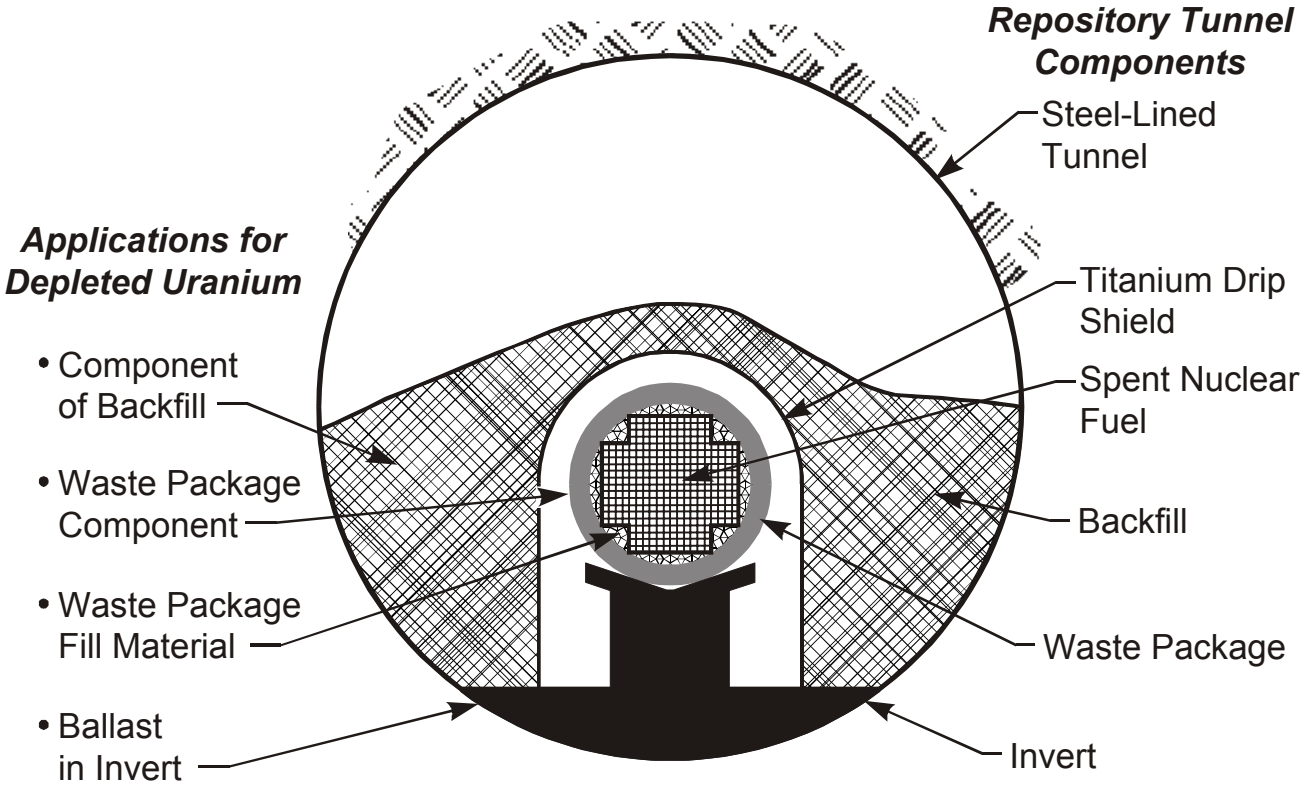
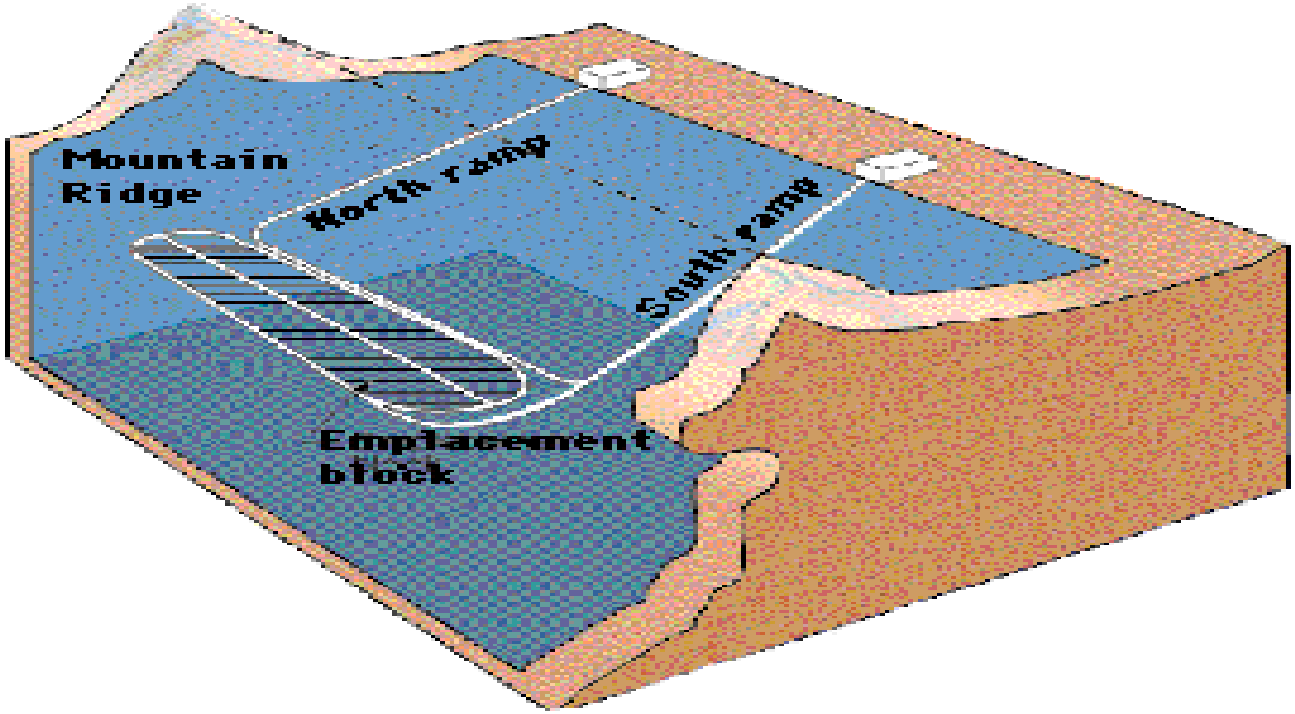
Spin Casting of Cermet Cask Body
(Future Option)



Cross Section of Yucca Mountain Disposal Drift with Waste Package System



Potential Applications of DU in the Proposed Yucca Mountain Repository



Yucca Mountain (YM) Repository